



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.04.2016 Bulletin 2016/15

(51) Int Cl.:
F25B 47/02 (2006.01) F25B 1/00 (2006.01)

(21) Application number: **13885959.0**

(86) International application number:
PCT/JP2013/065210

(22) Date of filing: **31.05.2013**

(87) International publication number:
WO 2014/192140 (04.12.2014 Gazette 2014/49)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

- **WAKAMOTO, Shinichi**
Tokyo 100-8310 (JP)
- **WATANABE, Kazuya**
Tokyo 100-8310 (JP)
- **YAMASHITA, Koji**
Tokyo 100-8310 (JP)
- **HATOMURA, Takeshi**
Tokyo 100-8310 (JP)

(71) Applicant: **Mitsubishi Electric Corporation**
Tokyo 100-8310 (JP)

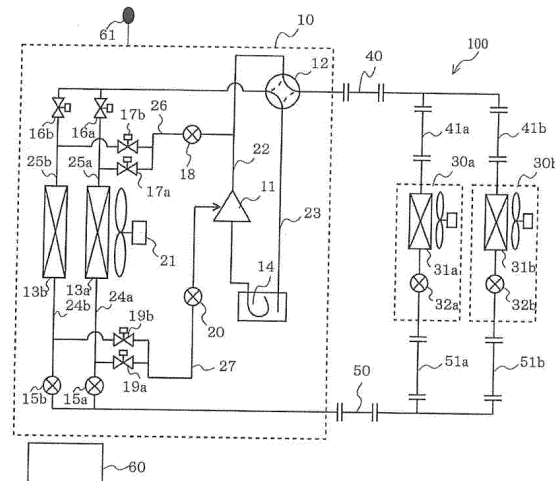
(74) Representative: **Sajda, Wolf E.**
Meissner, Bolte & Partner GbR
Postfach 86 06 24
81633 München (DE)

(72) Inventors:
• **TAKENAKA, Naofumi**
Tokyo 100-8310 (JP)

(54) **AIR CONDITIONER**

(57) An air-conditioning apparatus includes: a compressor (11) allowing refrigerant injection and compress and discharge the refrigerant at a high temperature; an indoor heat exchanger (31) exchanging heat between air and refrigerant; a first flow rate control device (32) adjusting and controlling a flow rate of refrigerant; and a plurality of outdoor heat exchangers (13 being in parallel to exchange heat between outside air and refrigerant; a first defrosting pipe (26) allowing a branched part of the refrigerant discharged from the compressor (11) to pass and flow into the outdoor heat exchanger (13) to be defrosted; a reducing device (18) adjusting a pressure of refrigerant passing through the first defrosting pipe (26) to a medium pressure; a second defrosting pipe (27) from which the refrigerant that has passed through the outdoor heat exchanger (13) to be defrosted is injected into the compressor (11); and a reducing device (20) adjusting a pressure of refrigerant passing through the second defrosting pipe (27) to an injection pressure.

FIG. 1



DescriptionTechnical Field

5 **[0001]** The present invention relates to an air-conditioning apparatus.

Background Art

10 **[0002]** In view of global environmental protection, boiler-type heating appliances for heating by burning fossil fuel have been replaced by heat-pump-type air-conditioning apparatuses using air as heat sources in more and more cases even in cold regions in recent years. The heat-pump-type air-conditioning apparatus can efficiently perform heating because heat is supplied from air in addition to an electrical input to a compressor.

15 **[0003]** On the other hand, in the heat-pump-type air-conditioning apparatus, however, frost is more easily accumulated on an outdoor heat exchanger serving as an evaporator as the temperature of air in, for example, the outside (outdoor-air temperature) decreases. Thus, it is necessary to perform defrosting (frost removal) for melting frost on the outdoor heat exchanger.

[0004] For such defrosting, an example method is to reverse a refrigerant flow in heating so as to supply refrigerant from a compressor to an outdoor heat exchanger. This method, however, is performed while heating of a room is stopped in some cases, and thus, has the problem of a loss of comfort.

20 **[0005]** In view of this, to perform heating during defrosting, proposed are methods for heating by dividing outdoor heat exchangers in such a manner that while some of the outdoor heat exchangers are defrosted, the other outdoor heat exchangers operate as evaporators so as to absorb heat from air, for example (e.g., Patent Literature 1, Patent Literature 2, and Patent Literature 3).

25 **[0006]** For example, in a technique described in Patent Literature 1, an outdoor heat exchanger is divided into two heat exchanger parts. Then, to defrost one of the heat exchanger parts, an electronic expansion valve disposed upstream of this heat exchanger part is closed. In addition, an electromagnetic shut-off valve of a bypass pipe for conveying refrigerant from a discharge pipe of a compressor to an inlet of the heat exchanger part for bypassing is opened so that part of high-temperature refrigerant discharged from the compressor flows directly into the heat exchanger part to be defrosted.

30 **[0007]** When defrosting of one of the heat exchanger parts is completed, defrosting of the other heat exchanger part is performed. In this case, in a heat exchanger part to be defrosted, defrosting is performed in a state in which the pressure of refrigerant in this heat exchanger part is substantially equal to a suction pressure of the compressor (low-pressure defrosting).

35 **[0008]** In a technique described in Patent Literature 2, a plurality of heat source units and at least one indoor unit are provided, and refrigerant discharged from a compressor is caused to flow directly into a heat source unit side heat exchanger to be defrosted by reversing connection of a four-way valve of only a heat source unit including the heat source side heat exchanger to be defrosted.

40 **[0009]** In this case, in the heat source unit side heat exchanger to be defrosted, defrosting is performed in a state in which the pressure of refrigerant in this heat source unit side heat exchanger is substantially equal to a discharge pressure of the compressor (high-pressure defrosting).

45 **[0010]** In a technique described in Patent Literature 3, an outdoor heat exchanger is divided into a plurality of outdoor heat exchanger parts in such a manner that part of high-temperature refrigerant discharged from a compressor alternately flows into the outdoor heat exchanger parts so as to alternately defrost the outdoor heat exchanger parts. Thus, heating can be continuously performed without reversing a refrigeration cycle. Refrigerant supplied to an outdoor heat exchanger part to be defrosted is injected from an injection port of the compressor.

50 **[0011]** In this case, in the outdoor heat exchanger part to be defrosted, defrosting is performed in a state in which the pressure of refrigerant in this outdoor heat exchanger part is lower than a discharge pressure of the compressor and higher than a suction pressure of the compressor (a pressure that is slightly higher than 0 °C in terms of saturation temperature) (medium-pressure defrosting).

List of CitationsPatent Literature

55 **[0012]**

Patent Literature 1: Japanese Unexamined Patent Application Publication JP 2009-085 484 A ([0019], FIG. 3)

Patent Literature 2: Japanese Unexamined Patent Application Publication JP 2007-271 094 A([0007], FIG. 2)

Summary of the InventionTechnical Problem

[0013] In the low-pressure defrosting described in Patent Literature 1, a heat exchanger part to be defrosted and a heat exchanger part serving as an evaporator (i.e., a heat exchanger part not to be defrosted) operate in the same pressure range. In the heat exchanger part serving as an evaporator, refrigerant takes heat from outdoor air. Thus, an evaporating temperature of refrigerant needs to be lower than an outdoor-air temperature.

[0014] To achieve this, in the heat exchanger part to be defrosted, a saturation temperature of refrigerant is lower than or equal to 0 °C in some cases. Accordingly, condensation latent heat of refrigerant cannot be used for melting frost (0 °C), and the efficiency of defrosting is low in some cases.

[0015] In the high-pressure defrosting described in Patent Literature 2, subcooling (the degree of subcooling) of refrigerant at an outlet of a heat source side heat exchanger whose defrosting has finished increases. Thus, temperature distribution occurs in a heat source side heat exchanger to be defrosted, and efficient defrosting cannot be performed.

[0016] In addition, a large degree of subcooling causes an increase in the amount of liquid refrigerant in the heat source side heat exchanger to be defrosted, and thus, it takes time for liquid refrigerant to move in some cases.

[0017] In the medium-pressure defrosting described in Patent Literature 3, condensation latent heat is utilized by controlling the saturation temperature of refrigerant in a state (about 0 °C to 10 °C) slightly higher than zero. This medium-pressure defrosting shows a small temperature variation of the entire outdoor heat exchanger parts as compared to the low-pressure defrosting and the high-pressure defrosting, and thus, defrosting can be efficiently performed.

[0018] However, the amount of liquid of refrigerant that can be injected into the compressor is limited, and the flow rate of refrigerant that can be supplied to the outdoor heat exchanger part to be defrosted is limited. In addition, the pressure of the outdoor heat exchanger part to be defrosted might be affected by an injection pressure of an injection compressor. Thus, defrosting capacity is limited, and the time cannot be shortened.

[0019] The present invention has been made to solve problems as described above, and it is therefore an object of the present invention to provide an air-conditioning apparatus that can efficiently perform defrosting.

Solution to Problem

[0020] An air-conditioning apparatus according to the present invention includes:

a compressor configured to allow refrigerant to be injected into a portion located intermediate of a compression stroke, suck refrigerant having a low pressure, compress the refrigerant, and discharge refrigerant having a high temperature;

an indoor heat exchanger configured to exchange heat between air to be conditioned and the refrigerant;

a first flow rate control device configured to adjust and control a flow rate of the refrigerant passing through the indoor heat exchanger;

a plurality of outdoor heat exchangers connected in parallel and configured to exchange heat between outdoor air and the refrigerant, the compressor, the indoor heat exchanger, the first flow rate control device, and the plurality of outdoor heat exchangers being connected by pipes and forming a main refrigerant circuit in which the refrigerant circulates;

a first defrosting pipe through which a branched part of the refrigerant discharged from the compressor passes and flows into at least one of the outdoor heat exchangers to be defrosted;

a first pressure adjustment device configured to adjust the refrigerant passing through the first defrosting pipe to a medium pressure higher than the low pressure and lower than the high pressure;

a second defrosting pipe from which the refrigerant that has passed through the at least one of the outdoor heat exchangers to be defrosted is injected into the compressor; and a second pressure adjustment device configured to adjust a pressure of refrigerant passing through the second defrosting pipe to an injection pressure.

Advantageous Effects of the Invention

[0021] The present invention provides an air-conditioning apparatus in which defrosting is performed by causing refrigerant to flow into an outdoor heat exchanger to be defrosted through a path different from a main refrigerant circuit under a pressure adjusted by a first pressure adjustment device and a second pressure adjustment device. Thus, the defrosting can be efficiently performed without stopping heating of an indoor unit, for example.

Brief Description of the Drawings**[0022]**

- 5 FIG. 1 illustrates a configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 2 illustrates an example configuration of an outdoor heat exchanger of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 10 FIG. 3 is a table showing states of ON/OFF (opening/closing) or opening degree adjustment of devices having valves in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- Fig. 4 is a view showing a flow of refrigerant in a cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 5 is a P-h diagram in the cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 15 FIG. 6 is a view showing a flow of refrigerant in a heating normal operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 7 is a P-h diagram in the heating normal operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 8 is a view showing a flow of refrigerant in a heating defrosting operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 20 FIG. 9 is a P-h diagram in the heating defrosting operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 10 shows a heating capacity ratio with respect to a pressure (in terms of saturated liquid temperature) of an outdoor heat exchanger 13 to be defrosted in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 25 FIG. 11 shows an enthalpy difference between before inflow and after outflow of refrigerant into/from an outdoor heat exchanger 13 to be defrosted with respect to the pressure (in terms of saturated liquid temperature) in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 12 shows a flow rate ratio of the outdoor heat exchanger 13 to be defrosted with respect to the pressure (in terms of saturated liquid temperature) in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 30 FIG. 13 shows a refrigerant amount of the outdoor heat exchanger 13 to be defrosted with respect to the pressure (in terms of saturated liquid temperature) in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 35 FIG. 14 shows a subcooling SC of refrigerant at an outlet of the at least one of the outdoor heat exchangers to be defrosted with respect to the pressure (in terms of saturated liquid temperature) of the outdoor heat exchanger 13 to be defrosted in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- FIG. 15 is a flowchart showing control of a control device 60 in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
- 40 FIG. 16 illustrates a configuration of an air-conditioning apparatus 101 according to Embodiment 2 of the present invention.
- FIG. 17 is a table showing states of ON/OFF (opening/closing) or opening degree adjustment of devices having valves in the air-conditioning apparatus 100 according to Embodiment 2 of the present invention.
- 45 FIG. 18 is a view showing a flow of refrigerant in a heating defrosting operation of the air-conditioning apparatus 101 according to Embodiment 2 of the present invention.
- FIG. 19 is a P-h diagram in the heating defrosting operation of the air-conditioning apparatus 101 according to Embodiment 2 of the present invention.
- FIG. 20 illustrates a configuration of an air-conditioning apparatus 102 according to Embodiment 3 of the present invention.
- 50 FIG. 21 illustrates a configuration of an air-conditioning apparatus 103 according to Embodiment 4 of the present invention.
- FIG. 22 illustrates a configuration of an air-conditioning apparatus 104 according to Embodiment 4 of the present invention.
- 55

Description of Embodiments

[0023] Embodiments of the present invention will be described with reference to the drawings. In the drawings, the

same reference characters designate the same or like components, and the same holds for the entire description of the specification. The configurations of components in the following description are merely examples, and the present invention is not limited to these examples. In particular, combinations of components are not limited to those in the embodiments, and components in one embodiment are applicable to another embodiment.

[0024] Similar devices distinguished by suffixes, for example, may be collectively referred to without the suffixes when these devices do not need to be individually distinguished or specified. The levels of, for example, temperature and pressure are not determined based on specific absolute values, and are determined relative to the states, operation, and other factors in, for example, a system or a device.

Embodiment 1

[0025] FIG. 1 illustrates a configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present invention. The air-conditioning apparatus 100 of this Embodiment includes an outdoor unit 10 and a plurality of indoor units 30a and 30b. The outdoor unit 10 is connected to the indoor units 30a and 30b by first extension pipes 40, 41a, and 41b and second extension pipes 50, 51a, and 51b, thereby forming a refrigerant circuit. In the refrigerant circuit, the indoor unit 30a and the indoor unit 30b are connected in parallel with the outdoor unit 10.

[0026] The air-conditioning apparatus 100 includes a control device 60. The control device 60 performs a process based on, for example, a temperature and a pressure detected by detectors (sensors) provided in the air-conditioning apparatus 100, controls devices in the air-conditioning apparatus 100, and controls cooling and heating of a space to be air-conditioned performed at least one of the indoor unit 30a or 30b. An outdoor-air temperature sensor 61 is a temperature detector for detecting an outdoor temperature.

[0027] The air-conditioning apparatus according to this Embodiment also includes a pressure sensor and a temperature sensor for detecting a pressure and a temperature of refrigerant discharged and sucked from/into the compressor 11. The air-conditioning apparatus also includes, for example, temperature sensors for detecting, for example, temperatures of refrigerant in outdoor heat exchangers 13 and an indoor heat exchanger 31.

[0028] Examples of refrigerant circulating in a refrigerant circuit include fluorocarbon refrigerant and HFO refrigerant. Examples of the fluorocarbon refrigerant include a HFC-based refrigerant such as R32 refrigerant, R125, and R134a, and a refrigerant mixture of these refrigerants, such as R410A, R407c, or R404A.

[0029] Examples of the HFO refrigerant include HFO-1234yf, HFO-1234ze (E), and HFO-1234ze (Z). Examples of other refrigerants include refrigerants for use in vapor compression heat pumps, such as CO₂ refrigerant, HC refrigerant (e.g., propane or isobutane refrigerant), ammonia refrigerant, and refrigerant mixture of R32 and HFO-1234yf.

[0030] In the air-conditioning apparatus 100 of this Embodiment 1, the two indoor units 30a and 30b are connected to one outdoor unit 10. Alternatively, only one indoor unit 30 may be provided, or three such indoor units may be connected in parallel. Two or more outdoor units 10 may also be connected to in parallel.

[0031] In addition, a refrigerant circuit configuration may be employed in such a manner that cooling and heating can be simultaneously performed, that is, each of the indoor units 30 is individually allowed to select cooling or heating by, for example, providing a switching valve in the indoor unit 30.

[0032] A configuration of the refrigerant circuit in the air-conditioning apparatus 100 will now be described. The refrigerant circuit of the air-conditioning apparatus 100 includes a refrigerant circuit serving as a main circuit (main refrigerant circuit) formed by connecting the compressor 11, a cooling/heating switching device 12, and an outdoor heat exchanger 13 of the outdoor unit 10 to an indoor heat exchanger 31 and a first flow rate control device 32 that is freely opened and closed of the indoor unit 30 by pipes. In this embodiment, although an accumulator 14 is connected to the main refrigerant circuit, the accumulator 14 is not a necessary component, and thus, may not be connected to the main refrigerant circuit.

[0033] The compressor 11 sucks refrigerant, compresses the refrigerant into a high-temperature high-pressure gaseous state, and discharges the resulting refrigerant. The compressor 11 of this Embodiment includes a port that allows injection (refrigerant introduction) into a portion located intermediate of a compression stroke in a compression chamber (not shown). For example, a discharge temperature can be reduced, for example, by injecting liquid refrigerant under a predetermined pressure (injection pressure).

[0034] The compressor 11 is a compressor of a type that can control the rotation speed (driving frequency) by using, for example, an inverter circuit so as to change the discharge amount (discharge capacity) of refrigerant. The cooling/heating switching device 12 is connected to a point between a discharge pipe 22 and a suction pipe 23 of the compressor 11 and switches the direction of refrigerant flow.

[0035] The cooling/heating switching device 12 is constituted by, for example, a four-way valve. Based on an instruction of the control device 60, the cooling/heating switching device 12 switches between a pipe connection state indicated by continuous lines in FIG. 1 in a heating operation and a pipe connection state indicated by broken lines in FIG. 1 in a cooling operation.

[0036] FIG. 2 illustrates an example configuration of the outdoor heat exchanger 13 of the air-conditioning apparatus

100 according to Embodiment 1 of the present invention. As illustrated in FIG. 2, the outdoor heat exchanger of this Embodiment is a fin-and-tube heat exchanger including a plurality of heat transfer tubes 5a and a plurality of fins 5b, for example.

[0037] The heat transfer tubes 5a allow refrigerant to pass therethrough and are arranged in a plurality of levels extending perpendicularly to direction of passage of air and a plurality of columns extending in parallel with the direction of passage of air. The fins 5b are spaced from one another in such a manner that air passes therethrough in the direction of passage of air.

[0038] As illustrated in FIG. 2, for the outdoor heat exchanger 13 of this embodiment, one outdoor heat exchanger includes a plurality of independent channels. This outdoor heat exchanger is divided into a plurality of outdoor heat exchangers 13 by inlets and outlets of the channels in parallel with the refrigerant main circuit. In this example, the outdoor heat exchanger is divided into two outdoor heat exchangers 13a and 13b. The outdoor heat exchanger is not necessarily divided into two.

[0039] The outdoor heat exchanger may be divided into left and right exchangers (i.e., horizontal division). In this case, however, the inlet and outlet of refrigerant of each of the outdoor heat exchangers 13a and 13b are separated at the left and right ends of the outdoor unit 10, which complicates connection of pipes. In view of this, the outdoor heat exchanger is preferably divided into upper and lower exchangers (i.e., vertical division) as illustrated in FIG. 2.

[0040] In addition, as illustrated in FIG. 2, the fins 5b are common to the outdoor heat exchangers 13a and 13b of this embodiment, that is, are not divided. Thus, in a heating defrosting operation described later, high-temperature refrigerant flows in the heat transfer tubes 5a and heats the fins 5b in order to melt frost in one of the outdoor heat exchangers 13, whereas refrigerant flowing in the heat transfer tubes 5a takes heat through the fins 5b in the other outdoor heat exchanger 13.

[0041] In view of this, to prevent leakage of heat between the outdoor heat exchangers 13, the fins 5b are divided into parts individually corresponding to the outdoor heat exchangers 13.

[0042] An outdoor fan 21 causes air in the outside (outdoor air) to pass through the outdoor heat exchangers 13a and 13b so as to promote heat exchange with refrigerant. In FIG. 1, one outdoor fan 21 is provided for the outdoor heat exchangers 13a and 13b, but may be provided for each of the outdoor heat exchangers 13a and 13b.

[0043] First connection pipes 24a and 24b are connected to the outdoor heat exchangers 13a and 13b, respectively. In this embodiment, the connection pipes 24a and 24b are connected to the refrigerant inflow ends of the outdoor heat exchangers 13a and 13b in a heating operation. Second flow rate control devices 15a and 15b are provided in channels of the first connection pipes 24a and 24b, respectively. The second flow rate control devices 15a and 15b are constituted by electronically controlled expansion valves.

[0044] Based on an instruction from the control device 60, the second flow rate control devices 15a and 15b change the opening degrees thereof so as to control a flow rate of refrigerant by pressure adjustment. The second flow rate control devices 15a and 15b of Embodiment 1 correspond to a "third pressure adjustment device" of the present invention.

[0045] Second connection pipes 25a and 25b are connected to the outdoor heat exchangers 13a and 13b, respectively, at the opposite ends to the first connection pipes 24a and 24b. In this embodiment, the second connection pipes 25a and 25b are connected to refrigerant outflow ends of the outdoor heat exchangers 13a and 13b in the heating operation.

[0046] First solenoid valves 16a and 16b are provided in channels of the second connection pipes 25a and 25b, respectively. Based on an instruction from the control device 60, each of the first solenoid valves 16a and 16b switches, by opening and closing the valve, as to whether or not refrigerant flows into/from the outdoor heat exchangers 13a and 13b from the main refrigerant circuit.

[0047] The air-conditioning apparatus 100 of this Embodiment further includes a first defrosting pipe 26 as a channel different from the refrigerant main circuit. The first defrosting pipe 26 has one end connected to the discharge pipe 22 and the other end branched into parts respectively connected to the second connection pipes 25a and 25b.

[0048] The first defrosting pipe 26 supplies part of high-temperature high-pressure refrigerant discharged from the compressor 11 to at least one of the outdoor heat exchangers 13a and 13b for defrosting. The first defrosting pipe 26 includes a reducing device 18. Based on an instruction from the control device 60, the reducing device 18 reduces the pressure of part of the high-temperature high-pressure refrigerant discharged from the compressor 11 to a medium pressure.

[0049] The medium pressure herein is a pressure lower than a high pressure (discharge pressure) and higher than an injection pressure and a low pressure (suction pressure). Thus, in defrosting, the refrigerant whose pressure has been reduced to the medium pressure is supplied to the outdoor heat exchangers 13a and 13b. Second solenoid valves 17a and 17b are provided in branched parts of the first defrosting pipe 26.

[0050] Each of the second solenoid valves 17a and 17b switches as to whether or not refrigerant flows into the second connection pipes 25a and 25b from the discharge pipe 22 through the first defrosting pipe 26. The reducing device 18 corresponds to a "first pressure adjustment device" of the present invention.

[0051] The first solenoid valves 16a and 16b and the second solenoid valves 17a and 17b only need to switch channels between the main refrigerant circuit and the first defrosting pipe 26. Thus, the first solenoid valves 16a and 16b and the

second solenoid valves 17a and 17b may be constituted by four-way valves, three-way valves, or two way valves, for example. For example, each of the first solenoid valves 16a and 16b reverses the pressures at the front and rear thereof because refrigerant therein flows in different directions in different operations. A typical solenoid valve cannot be used in some cases when the front and rear pressures are reversed.

[0052] In view of this, a four-way valve whose high-pressure sides are connected to the discharge pipe 22 and low-pressure sides are connected to the suction pipe 23 can be employed so as to have the same function as the first solenoid valves 16a and 16b. Since the sides of the second solenoid valves 17a and 17b connected to the first defrosting pipe 26 at the discharge pipe 22 are always at high pressures, and thus, may be two way valves each of which switches in two directions.

[0053] The reducing device 18 may be constituted by a capillary tube as long as a necessary defrosting capacity (the flow rate of refrigerant to flow into the first defrosting pipe 26 for defrosting) is determined. The sizes of the second solenoid valves 17a and 17b may be reduced without using the reducing device 18 so that the pressures thereof are reduced to a medium pressure at a predetermined defrosting flow rate.

[0054] A flow rate control device may be provided instead of the second solenoid valves 17a and 17b, without using the reducing device 18. In such cases, the second solenoid valves 17a and 17b or the flow rate control device, for example, corresponds to a "first pressure adjustment device" of the present invention.

[0055] The second defrosting pipe 27 also serve as a channel different from the refrigerant main circuit. The second defrosting pipe 27 has one end connected to a port at an injection portion of the compressor 11 and the other end branched into parts respectively connected to the first connection pipes 24a and 24b. The second defrosting pipe 27 includes a reducing device 20 and third solenoid valves 19a and 19b.

[0056] In a heating defrosting operation described later, the reducing device 20 reduces the pressure of part of medium-temperature medium-pressure refrigerant that has flowed from the outdoor heat exchanger 13a or 13b to an injection pressure. The refrigerant whose pressure has been reduced is injected into the compressor 11.

[0057] Each of the third solenoid valves 19a and 19b is provided at a branch point in the second defrosting pipe 27, and switches as to whether or not refrigerant flows from the first connection pipes 24a and 24b to the second defrosting pipe 27. The reducing device 20 corresponds to a "second pressure adjustment device" of the present invention.

[0058] Operational behaviors of operations performed by the air-conditioning apparatus 100 of this Embodiment will now be described. The operations performed by the air-conditioning apparatus 100 include two operations: a cooling operation and a heating operation. The heating operation includes a heating normal operation and a heating defrosting operation (also referred to as a continuous heating operation). In the heating normal operation, both the outdoor heat exchangers 13a and 13b constituting the outdoor heat exchangers 13 operate as evaporators. The heating defrosting operation is an operation in which the outdoor heat exchanger 13a and the outdoor heat exchanger 13b are alternately defrosted while a heating operation continues.

[0059] Specifically, a heating operation is performed with one of the outdoor heat exchangers 13 operating as an evaporator, whereas the other outdoor heat exchanger 13 is defrosted. When the defrosting of the latter outdoor heat exchanger 13 is finished, this outdoor heat exchanger then operates as an evaporator to perform a heating operation, whereas the former outdoor heat exchanger 13 is defrosted.

[0060] FIG. 3 is a table showing states of ON/OFF (opening/closing) or opening degree adjustment of devices (valves) having valves in operations of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 3, with regard to the cooling/heating switching device 12, ON represents a connection state indicated by the continuous lines in FIG. 1, whereas OFF represents a connection state indicated by the broken lines in FIG. 1.

[0061] With regard to each of the solenoid valves 16a, 16b, 17a, 17b, 19a, and 19b, ON represents a state in which the valve is open so that refrigerant flows, whereas OFF represents a state in which the valve is closed so that refrigerant does not flow.

Cooling Operation

[0062] FIG. 4 is a view showing a flow of refrigerant in a cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 4, bold lines represent sections where refrigerant flows in the cooling operation, and thin lines represent sections where refrigerant does not flow. FIG. 5 is a P-h diagram in the cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 5, point (a) to point (d) represent the states of refrigerant at points denoted by the same characters in FIG. 4.

[0063] When an operation starts, the compressor 11 sucks low-temperature low-pressure gas refrigerant through the suction pipe 23, compresses the refrigerant, and discharges high-temperature high-pressure gas refrigerant. In this refrigerant compression process of the compressor 11, refrigerant is compressed with heat to a degree corresponding to an adiabatic efficiency of the compressor 11, as compared to adiabatic compression represented by an isentrope, as indicated by a curve from point (a) to point (b) in FIG. 5.

[0064] High-temperature high-pressure gas refrigerant discharged from the compressor 11 passes through the cool-

ing/heating switching device 12 to be branched into two refrigerant parts. One of the two refrigerant parts passes through the first solenoid valve 16a and flows into the outdoor heat exchanger 13a from the second connection pipe 25a. The other passes through the first solenoid valve 16b and flows into the outdoor heat exchanger 13b from the second connection pipe 25b.

[0065] The refrigerant that has flowed into the outdoor heat exchangers 13a and 13b is cooled while heating outdoor air through heat exchange with the outdoor air and becomes a medium-temperature high-pressure liquid refrigerant. In consideration of a pressure loss in the outdoor heat exchangers 13, a refrigerant change in the outdoor heat exchangers 13a and 13b is represented a slightly tilted approximately horizontal line indicated by a line from point (b) to point (c) in FIG. 5.

[0066] Here, heat exchange is performed in both of the outdoor heat exchangers 13a and 13b. Alternatively, in a case where the operation capacities of the indoor units 30a and 30b are small, for example, the first solenoid valve 16b may be closed so that no refrigerant flows into the outdoor heat exchanger 13b. By preventing refrigerant from flowing, the heat transfer area of the outdoor heat exchangers 13 decreases consequently, thereby performing an operation in stable cycles.

[0067] The medium-temperature high-pressure liquid refrigerants that have flowed out from the outdoor heat exchangers 13a and 13b respectively flow into the first connection pipes 24a and 24b, pass through the second flow rate control devices 15a and 15b in fully opened states, and then are combined. The combined refrigerant flows out of the outdoor unit 10. Then, the refrigerant passes through the second extension pipes 50, 51a, and 51b and flows into the indoor units 30a and 30b. The refrigerant then passes through first flow rate control devices 32a and 32b.

[0068] While passing through the first flow rate control devices 32a and 32b, the refrigerant is expanded and has its pressure reduced and becomes refrigerant in a low-temperature low-pressure two-phase gas-liquid state. The change of refrigerant in the first flow rate control devices 32a and 32b is performed under a constant enthalpy. The refrigerant change at this time is represented by a vertical line from point (c) to point (d) in FIG. 5.

[0069] The refrigerant in the low-temperature low-pressure two-phase gas-liquid state that has flowed out of the first flow rate control devices 32a and 32b flows into indoor heat exchangers 31a and 31b. The refrigerant that has flowed into the indoor heat exchangers 31a and 31b is heated while cooling indoor air through heat exchange with the indoor air, and becomes low-temperature low-pressure gas refrigerant.

[0070] Here, the control device 60 controls the opening degrees of the first flow rate control devices 32a and 32b in such a manner that the superheat (degree of superheat) of the low-temperature low-pressure gas refrigerant from the indoor heat exchangers 31a and 31b is about 2 K to 5 K. In consideration of a pressure loss, the change of refrigerant in the indoor heat exchangers 31a and 31b is represented by a slightly tilted approximately horizontal line indicated by a line from point (e) to point (a) in FIG. 5.

[0071] The low-temperature low-pressure gas refrigerant that has flowed out of the indoor heat exchangers 31a and 31b flows out of the indoor units 30a and 30b. The refrigerant then passes through the first extension pipes 41a, 41b, and 40 and flows into the outdoor unit 10. Thereafter, the refrigerant passes through the cooling/heating switching device 12 and the accumulator 14 and is sucked into the compressor 11 through the suction pipe 23.

Heating Normal Operation

[0072] FIG. 6 is a view showing a flow of refrigerant in a heating normal operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 6, bold lines represent sections where refrigerant flows in the heating normal operation, and thin lines represent sections where refrigerant does not flow. FIG. 7 is a P-h diagram in the heating normal operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 7, point (a) to point (e) represent the states of refrigerant at points denoted by the same characters in FIG. 6.

[0073] When an operation starts, the compressor 11 sucks low-temperature low-pressure gas refrigerant through the suction pipe 23, compresses the refrigerant, and discharges high-temperature high-pressure gas refrigerant. The refrigerant compression process of the compressor 11 is represented by a curve from point (a) to point (b) in FIG. 7.

[0074] The high-temperature high-pressure gas refrigerant discharged from the compressor 11 passes through the cooling/heating switching device 12 and then flows out of the outdoor unit 10. The high-temperature high-pressure gas refrigerant that has flowed out of the outdoor unit 10 flows into the indoor units 30a and 30b through the first extension pipes 40, 41a, and 41b. The refrigerant then flows into the indoor heat exchangers 31a and 31b.

[0075] The refrigerant that has flowed into the indoor heat exchangers 31a and 31b is cooled while heating indoor air through heat exchange with the indoor air, and becomes medium-temperature high-pressure liquid refrigerant. The change of refrigerant in the indoor heat exchangers 31a and 31b is represented by a slightly tilted approximately horizontal line from point (b) to point (c) in FIG. 7.

[0076] The medium-temperature high-pressure liquid refrigerant that has flowed out of the indoor heat exchangers 31a and 31b passes through the first flow rate control devices 32a and 32b. While passing through the first flow rate control devices 32a and 32b, the refrigerant is expanded and has its pressure reduced and becomes refrigerant in a

medium-pressure two-phase gas-liquid state. The change of refrigerant at this time is represented by a vertical line from point (c) to point (d) in FIG. 7.

[0077] The control device 60 controls the opening degrees of the first flow rate control devices 32a and 32b in such a manner that the subcooling (degree of subcooling) of the medium-temperature high-pressure liquid refrigerant is about 5 K to 20 K. The refrigerant in the medium-pressure two-phase gas-liquid state that has flowed out of the first flow rate control devices 32a and 32b flows out of the indoor units 30a and 30b.

[0078] The refrigerant that has flowed out of the indoor units 30a and 30b flows into the outdoor unit 10 through the second extension pipes 51a, 51b, and 50. The refrigerant that has flowed into the outdoor unit 10 flows into the first connection pipes 24a and 24b. The refrigerant that has flowed into the first connection pipes 24a and 24b passes through the second flow rate control devices 15a and 15b.

[0079] While passing through the second flow rate control devices 15a and 15b, the refrigerant is expanded and has its pressure reduced and becomes a low-pressure two-phase gas-liquid state. The change of refrigerant at this time is represented by a curve from point (d) to point (e) in FIG. 7.

[0080] The control device 60 controls the opening degrees of the second flow rate control devices 15a and 15b in such a manner that the opening degrees are fixed at a constant opening degree (e.g., in a fully open state) or an intermediate-pressure saturation temperature of the second extension pipe 50, for example, is about 0 to 20 °C.

[0081] The refrigerant that has passed through the second flow rate control devices 15a and 15b flows into the outdoor heat exchangers 13a and 13b. The refrigerant that has flowed into the outdoor heat exchangers 13a and 13b is heated while cooling outdoor air through heat exchange with the outdoor air and becomes low-temperature low-pressure gas refrigerant. The change of refrigerant in the outdoor heat exchangers 13a and 13b is represented by a slightly tilted approximately horizontal line from point (e) to point (a) in FIG. 7.

[0082] The low-temperature low-pressure gas refrigerants that have flowed out of the outdoor heat exchangers 13a and 13b respectively flow into the second connection pipes 25a and 25b, pass through the first solenoid valves 16a and 16b, and then are combined. The combined refrigerant passes through the cooling/heating switching device 12 and the accumulator 14 and is sucked into the compressor 11 through the suction pipe 23.

Heating Defrosting Operation (Continuous Heating Operation)

[0083] A heating defrosting operation is performed when the control device 60 determines that frost is accumulated on the outdoor heat exchangers 13 in the heating normal operation. A plurality of methods can be employed to determine the presence of frost accumulation on the outdoor heat exchangers 13. As one example, frost is determined to be accumulated if a saturation temperature obtained by conversion from a suction pressure of the compressor 11 is determined to decrease significantly from a predetermined outdoor-air temperature.

[0084] As another example, frost is determined to be accumulated if a temperature difference between an outdoor-air temperature and an evaporating temperature in the outdoor heat exchangers 13 is determined to be greater than or equal to a predetermined difference for a predetermined period or longer.

[0085] In the configuration of the air-conditioning apparatus 100 according to Embodiment 1, while the outdoor heat exchanger 13b is being defrosted in the heating defrosting operation, the outdoor heat exchanger 13a serves as an evaporator so as to continue heating. In contrast, while the outdoor heat exchanger 13a is being defrosted, the outdoor heat exchanger 13b serves as an evaporator so as to continue heating.

[0086] Between the case of defrosting the outdoor heat exchanger 13a and the case of defrosting the outdoor heat exchanger 13b, the open/close states of the first solenoid valve 16, the second solenoid valve 17, and the third solenoid valve 19 are reversed and the flow of refrigerant in the outdoor heat exchangers 13 are different, but the other part of the operation is the same.

[0087] Thus, the following description is directed to the case where the outdoor heat exchanger 13b is defrosted and the outdoor heat exchanger 13a serves as an evaporator so as to continue heating in the heating defrosting operation. The same holds for the subsequent embodiments.

[0088] FIG. 8 is a view showing a flow of refrigerant in a heating defrosting operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 8, bold lines represent sections where refrigerant flows in defrosting of the outdoor heat exchanger 13b, and thin lines represent sections where refrigerant does not flow.

[0089] FIG. 9 is a P-h diagram in the heating defrosting operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In FIG. 9, point (a) to point (i) represent the states of refrigerant at points denoted by the same characters in FIG. 8.

[0090] The control device 60 determines which one of the outdoor heat exchangers 13 is to be defrosted. If it is determined that the outdoor heat exchanger 13b is to be defrosted, the first solenoid valve 16b corresponding to the outdoor heat exchanger 13b is closed. The control device 60 opens the second solenoid valve 17b and the third solenoid valve 19b and adjusts the reducing device 18 and the reducing device 20 to predetermined opening degrees.

[0091] In this manner, a refrigerant path (first refrigerant path) passing through the compressor 11, the reducing device

18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the second flow rate control device 15b, and the second flow rate control device 15a in this order is formed.

[0092] A refrigerant path (medium-pressure defrosting circuit, second refrigerant path) serving as an injection part and passing through the compressor 11, the reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the third solenoid valve 19b, the reducing device 20, and the compressor 11 in this order is also formed. Then, a heating defrosting operation starts.

[0093] When the heating defrosting operation starts, part of high-temperature high-pressure gas refrigerant discharged from the compressor 11 flows into the first defrosting pipe 26 and has its pressure reduced to a medium pressure in the reducing device 18. The change of refrigerant at this time is represented by a line from point (b) to point (f) in FIG. 9.

[0094] The refrigerant whose pressure has been reduced to the medium pressure represented by point (f) in FIG. 9 passes through the second solenoid valve 17b and the second connection pipe 25b, and flows into the outdoor heat exchanger 13b. The refrigerant that has flowed into the outdoor heat exchanger 13b is cooled through heat exchange with frost accumulated on the outdoor heat exchanger 13b.

[0095] In this manner, high-temperature high-pressure gas refrigerant discharged from the compressor 11 flows into the outdoor heat exchanger 13b so that frost accumulated on the outdoor heat exchanger 13b can be melted. The change of refrigerant at this time is represented as a change from point (f) to point (g) in FIG. 9. Here, refrigerant for defrosting has a saturation temperature higher than a frost temperature (0 °C) and lower than or equal to 10 °C.

[0096] Part of refrigerant after defrosting passes through the second flow rate control device 15b. The refrigerant that has passed through the second flow rate control device 15b is combined with refrigerant that has flowed into the outdoor unit 10 from the indoor unit 30 through the second extension pipes 51a, 51b, and 50 (point (h)).

[0097] The combined refrigerant flows into the outdoor heat exchanger 13a through the second flow rate control device 15a and the first connection pipe 24a. The refrigerant that has flowed into the outdoor heat exchanger 13a is heated while cooling outdoor air through heat exchange with the outdoor air and becomes low-temperature low-pressure gas refrigerant.

[0098] On the other hand, the other part of refrigerant that did not pass through the second flow rate control device 15b passes through the third solenoid valve 19b by way of the medium-pressure defrosting circuit described above. Then, the refrigerant has its pressure reduced to an injection pressure (point (i)) in the reducing device 20 and is injected into the compressor 11.

[0099] Then, a reason for setting the saturation temperature of refrigerant for refrigerant higher than 0 °C and lower than or equal to 10 °C will be described.

[0100] Figs. 10 to 14 are graphs in which the pressure (converted into a saturated liquid temperature in each graph) of refrigerant in the outdoor heat exchanger 13 to be defrosted with a fixed defrosting capacity. In this example, R410A refrigerant is used as refrigerant in the refrigerant circuit. FIG. 10 shows a change in heating capacity with respect to a pressure change of refrigerant. FIG. 11 shows a change of an enthalpy difference of refrigerant between before inflow and after outflow of refrigerant into/from the outdoor heat exchanger 13 to be defrosted with respect to a pressure change of refrigerant.

[0101] FIG. 12 shows a change of flow rate of refrigerant necessary for defrosting with respect to a pressure change of refrigerant. FIG. 13 shows a change of refrigerant amount in the accumulator 14 and the outdoor heat exchanger 13 with respect to a pressure change of refrigerant. FIG. 14 shows a change of subcooling SC at a refrigerant outlet of the outdoor heat exchanger 13 to be defrosted with respect to a pressure change of refrigerant.

[0102] FIG. 10 shows that the heating capacity of the outdoor heat exchanger 13 to be defrosted is high when the saturated liquid temperature of refrigerant is higher than 0 °C and is lower than or equal to 10 °C, and is low otherwise. First, a reason for the decrease of the heating capacity when the saturated liquid temperature is lower than or equal to 0 °C will be described. To melt frost, the temperature of refrigerant needs to be higher than 0 °C.

[0103] As shown in FIG. 10, when the saturated liquid temperature is reduced to 0 °C or less in order to melt frost, the location of point (g) in FIG. 9 becomes higher than the saturation gas enthalpy. Thus, condensation latent heat of refrigerant cannot be used, and the enthalpy difference between before inflow and after outflow of refrigerant into/from the outdoor heat exchanger 13 to be defrosted decreases (FIG. 11).

[0104] At this time, to show a defrosting capacity substantially equal to that of refrigerant whose saturation temperature is higher than 0 °C and lower than or equal to 10 °C, refrigerant in an amount about three to four times as much as refrigerant having a saturation temperature higher than 0 °C and lower than or equal to 10 °C needs to flow into the outdoor heat exchanger 13 to be defrosted. Thus, the amount of refrigerant that can be supplied to the indoor unit 30 for heating decreases, resulting in a decrease of the heating capacity.

[0105] Accordingly, when the saturated liquid temperature is 0 °C or less, the heating capacity decreases in a manner similar to the low-pressure defrosting described in Patent Literature 1. In view of this, the pressure of the outdoor heat exchanger 13 to be defrosted needs to be higher than 0 °C in terms of saturated liquid temperature.

[0106] On the other hand, as the pressure of the outdoor heat exchanger 13 to be defrosted increases, the subcooling SC at the refrigerant outlet of the outdoor heat exchanger 13 to be defrosted increases, as shown in FIG. 14. Accordingly,

the amount of liquid refrigerant increases, and the refrigerant density increases. In a typical multi-air-conditioning apparatus for buildings, the amount of necessary refrigerant is larger in cooling than in heating.

[0107] Thus, surplus refrigerant is usually present in a reservoir such as the accumulator 14 in a heating operation. However, when the amount of refrigerant necessary for the outdoor heat exchanger 13 to be defrosted increases with the increase in pressure as shown in FIG. 13, the amount of refrigerant accumulated in the accumulator 14 decreases so that the accumulator 14 becomes empty at a saturation temperature of about 10 °C.

[0108] When the accumulator 14 becomes empty of surplus refrigerant, shortage of refrigerant occurs in the refrigeration cycle so that the suction density of the compressor 11 decreases, for example, causing a decrease in the heating capacity. Although the upper limit of the saturation temperature can be increased by overcharging with refrigerant, the reliability of the air-conditioning apparatus might decrease because of, for example, overflow of liquid from the accumulator 14 in other operations. To prevent this, it is preferable to charge with an appropriate amount of refrigerant.

[0109] There is another problem that an increase in the saturation temperature causes a temperature variation in the temperature difference between refrigerant in the outdoor heat exchanger 13 and frost, and thus, there arise a place where frost is readily melted and a place where frost is not readily melted.

[0110] For the foregoing reasons, the pressure of the outdoor heat exchanger 13 to be defrosted is preferably higher than 0 °C and lower than or equal to 10 °C in terms of saturation temperature. To reduce variations in melting by suppressing refrigerant movement during defrosting while making the most of the medium-pressure defrosting using latent heat, an optimum target value is obtained in a case where the subcooling SC at the outlet of the outdoor heat exchanger 13 to be defrosted is 0 (zero) K.

[0111] In consideration of accuracies of, for example, a thermometer for detecting subcooling and a pressure gauge, the pressure of the outdoor heat exchanger 13 to be defrosted is preferably higher than 0 °C and lower than or equal to 6 °C in terms of saturation temperature in order to set the subcooling SC in the range from about 0 K to about 5 K.

[0112] Then, an example of operations of the reducing devices 18 and 20 and the second flow rate control devices 15a and 15b during a heating defrosting operation will be described. During the heating defrosting operation, the control device 60 controls the opening degree of the second flow rate control device 15b such that the pressure of the outdoor heat exchanger 13b to be defrosted is higher than 0 °C and lower than or equal to 10 °C in terms of saturation temperature.

[0113] On the other hand, regarding the opening degree, the second flow rate control device 15a is fully opened in order to enhance controllability by providing a differential pressure between before inflow and after outflow of refrigerant into/from the second flow rate control device 15b. The opening degree of the reducing device 18 is fixed in accordance with a predetermined necessary defrosting flow rate.

[0114] This is because the difference between the discharge pressure of the compressor 11 and the pressure of the outdoor heat exchanger 13b to be defrosted does not significantly change during the heating defrosting operation. In addition, the reducing device 20 is controlled to have such an opening degree that prevents liquid compression of refrigerant in the compressor 11 in order to maintain reliability.

[0115] The opening degree of the reducing device 20 is controlled to such a degree that refrigerant can be injected into the compressor 11 until the discharge superheat reaches about 10 K to 20K, for example, in order to control, for example, the discharge temperature and discharge superheat of the compressor 11 and, thereby, increase the flow rate of refrigerant flowing into the indoor heat exchanger 31 serving as a condenser. Here, heat released from refrigerant for defrosting does not only move to frost accumulated on the outdoor heat exchanger 13b but also partially moves to the outdoor air in some cases.

[0116] Thus, the control device 60 may control the reducing device 18 and the second flow rate control device 15b in such a manner that the flow rate increases as the outdoor-air temperature decreases. In this manner, the quantity of heat to be applied to frost is made constant, and thereby, the time for defrosting can be made constant, irrespective of the outdoor-air temperature.

[0117] The control device 60 may change the threshold value and the period of normal operation, for example, for use in determining the presence of frost accumulation, in accordance with the outdoor-air temperature. For example, the operating time is reduced so that the frost accumulation amount at the start of defrosting decreases as the outdoor-air temperature decreases in order to uniformize the quantity of heat applied to defrosting from refrigerant during the heating defrosting operation. In this manner, the resistance of the reducing device 18 can be made uniform. In addition, a reasonable capillary tube can be used. The control device 60 may set a threshold value to the outdoor-air temperature.

[0118] For example, in a case where the outdoor-air temperature is determined to be a threshold temperature or higher (e.g., in a case where the outdoor-air temperature is -5 °C or -10 °C), the heating defrosting operation is performed, whereas in a case where the outdoor-air temperature is determined to be lower than the threshold temperature, heating of the indoor unit 30 is stopped and all the outdoor heat exchangers are defrosted.

[0119] Specifically, in a case where the outdoor-air temperature is lower than or equal to 0 °C, such as -5 °C or -10 °C, the absolute humidity of outdoor air is originally low and the frost accumulation amount is small. Thus, the period of normal operation until the frost accumulation amount becomes constant increases.

[0120] Accordingly, even when heating of the indoor unit 30 is stopped and defrosting of all the outdoor heat exchangers

13 (full-surface defrosting) is performed, the proportion of a period in which heating of the indoor unit 30 is stopped is low. In the case of the heating defrosting operation, in consideration of heat transfer from the outdoor heat exchanger 13 to be defrosted to the outdoor air, a higher efficiency is obtained by performing full-surface defrosting with a heating operation stopped, for example, in some cases.

[0121] In view of this, a heating-stop defrosting operation mode in which full-surface defrosting is performed may be selected, in addition to the heating-and-defrosting operation mode. For example, defrosting can be efficiently performed by selecting an operation mode for defrosting based on the outdoor-air temperature.

[0122] In a case where the outdoor heat exchangers 13a and 13b are integrally formed and outdoor air is conveyed to the outdoor heat exchanger 13 to be defrosted by the outdoor fan 21, fan power may be changed to decrease as the outdoor-air temperature decreases. Thus, the amount of heat transferred from the outdoor heat exchanger 13 to be defrosted can be reduced in the heating defrosting operation.

Control Flow

[0123] FIG. 15 is a flowchart showing control of the control device 60 in the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. Referring to FIG. 15, a control process performed by the control device 60 in this Embodiment will be more specifically described. Here, the case of performing only a heating defrosting operation will be described with reference to FIG. 15.

[0124] When the air-conditioning apparatus 100 starts an operation (Step S1), it is determined whether or not the indoor units 30a and 30b perform heating (whether or not the operation mode is heating) (Step S2). If it is determined that the operation mode is cooling, control of a normal cooling operation is performed (Step S3).

[0125] On the other hand, if it is determined that the operation mode is heating, control of a normal heating operation is performed (Step S4). In the normal heating operation, in consideration of degradation of heat transmission performance of the outdoor heat exchanger 13 caused by decrease in, for example, heat transmission and the airflow rate due to frost accumulation, for example, it is determined whether or not conditions for starting a heating defrosting operation (whether or not frost is accumulated), based on Equation (1) (Step S5).

[0126] In Equation (1), x_1 is about 5 K to 20 K. If it is determined whether frost accumulation occurs or not by using a temperature sensor, a pressure sensor, and a sensor for measuring a frost accumulation amount, for example, the determination does not depend on a suction pressure with respect to conditions for starting defrosting.

(Saturation temperature of suction pressure)

[0127]

$$< (\text{outdoor-air temperature}) - x_1 \quad \dots(1).$$

[0128] For example, if it is determined that conditions for starting the heating defrosting operation are satisfied based on Equation (1), for example, a heating defrosting operation of defrosting the outdoor heat exchanger 13 starts. Here, control in the case of defrosting the outdoor heat exchanger 13b disposed at a lower stage and the outdoor heat exchanger 13a disposed at an upper stage in the outdoor heat exchangers 13 shown in FIG. 2 in this order will be described as an example. Thus, defrosting (medium-pressure defrosting) is first performed on the outdoor heat exchanger 13b (Step S6). The order of defrosting may be reversed.

[0129] As described above, the valves in a heating normal operation before a heating defrosting operation are in the states indicated in the level of "heating normal operation" in FIG. 3. From these states, the valves are changed to the states indicated in the level of "13a: Evaporator 13b: Defrosting" in "heating defrosting operation" in FIG. 3, and a heating defrosting operation is performed (Step S7).

(a) First solenoid valve 16b	OFF
(b) Second solenoid valve 17b	ON
(c) Third solenoid valve 19b	ON
(d) Reducing device 18	Open to a predetermined opening degree
(e) Reducing device 20	Open to a predetermined opening degree
(f) Second flow rate control device 15a	Fully open
(g) Second flow rate control device 15b	Control starts
(h) Reducing device 20	Control starts

[0130] It is determined whether defrosting end conditions are satisfied or not depending on melting of frost on the outdoor heat exchanger 13b to be defrosted (Step S8). If it is determined that the defrosting end conditions are not satisfied, a heating defrosting operation is performed in such a manner that the outdoor heat exchanger 13b is defrosted and the outdoor heat exchanger 13a serves as an evaporator.

[0131] Specifically, when the heating defrosting operation continues so that frost accumulated on the outdoor heat exchanger 13b starts being melted, the refrigerant temperature in the first connection pipe 24b increases. Thus, for the defrosting end conditions, the defrosting end conditions are determined to be satisfied if a temperature sensor attached to the first connection pipe 24b exceeds a threshold value as shown in Equation (2) below, for example. Here, x_2 is set at 3 °C to 10 °C, for example.

$$(\text{Refrigerant temperature of first connection pipe 24}) > x_2 \quad \dots(2).$$

[0132] If Equation (2) is satisfied and the defrosting end conditions are determined to be satisfied, defrosting of the outdoor heat exchanger 13b is finished (Step S9). At this time, the states of the valves are changed as follows:

(a) Second solenoid valve 17b	OFF
(b) Third solenoid valve 19b	OFF
(c) First solenoid valve 16b	ON
(d) Second flow rate control device 15a, 15b	Normal intermediate-pressure control

[0133] In addition, the valves are changed to the states indicated in the levels of "13a: Defrosting 13b: Evaporator" in "heating defrosting operation" in FIG. 3, and a heating defrosting operation in which the outdoor heat exchanger 13a is defrosted starts (S10). Although steps S10 to S13 are performed on the values indicated by reference numerals different from those in steps S6 to S9, steps S10 to S13 themselves are the same as steps S6 to S9.

[0134] When defrosting of both the lower-stage outdoor heat exchanger 13b and the upper-stage outdoor heat exchanger 13a is completed as described above and the heating defrosting operation indicated by Step S6 to Step S13 is finished, the process returns to Step S4, and a heating normal operation is performed.

[0135] Here, in a heating defrosting operation, the outdoor heat exchangers 13 are sequentially defrosted each at least once. Specifically, when defrosting of the last outdoor heat exchanger 13 is finished, a temperature sensor disposed in the refrigerant circuit, for example, determines that frost is accumulated on the initially defrosted outdoor heat exchanger 13 to degrade heat transmission performance, the initially defrosted outdoor heat exchanger 13 may be defrosted at the second time for a short time.

[0136] As described above, in the air-conditioning apparatus 100 according to Embodiment 1, a heating defrosting operation is performed in such a manner that defrosting is performed while refrigerant is sent toward the indoor unit 30. Thus, the room can be continuously heated. At this time, part of or the whole of refrigerant that has flowed out of the outdoor heat exchanger 13 that is being defrosted can be injected into the compressor 11 by adjusting the opening degree of at least one (mainly the reducing device 20) of the reducing device 20 or the second flow rate control device 15.

[0137] Thus, the amount of refrigerant supplied to the indoor unit 30 is increased so that heating capacity can be enhanced. In this operation, since each of the outdoor heat exchangers 13 is defrosted at least once, the efficiency in a normal heating operation can be increased.

[0138] In addition, part of refrigerant that has flowed out of the outdoor heat exchanger 13 being defrosted can be caused to flow into a main refrigerant circuit upstream of the outdoor heat exchanger 13 serving as an evaporator, by adjusting the opening degree of at least one (mainly the second flow rate control device 15) of the reducing device 20 and the second flow rate control device 15.

[0139] Thus, the defrosting efficiency can be enhanced, the amount of refrigerant flowing into the outdoor heat exchanger 13 serving as an evaporator increases, and the amount of heat absorption from the outdoor air increases. In addition, a decrease in the suction pressure of the compressor 11 can be suppressed.

[0140] Furthermore, the reducing device 20 is controlled to an opening degree at which refrigerant is injected in such a manner that the discharge superheat of refrigerant discharged from the compressor 11 is about 10 K to 20 K. Thus, the amount of refrigerant flowing into the indoor heat exchanger 31 serving as a condenser increases while the reliability is maintained so as to prevent refrigerant from liquid compression in the compressor 11, thereby enhancing the heating capacity.

[0141] In the air-conditioning apparatus 100 of this embodiment, part of high-temperature high-pressure gas refrigerant branched off from the discharge pipe 22 is subjected to pressure reduction to a pressure (medium pressure) higher than 0 °C and lower than or equal to 10 °C, in terms of saturation temperature, as compared to the temperature of frost, and the resulting refrigerant flows into the outdoor heat exchanger 13 to be defrosted. Thus, defrosting can be performed

while utilizing condensation latent heat of refrigerant.

[0142] In the air-conditioning apparatus 100 of this embodiment, the saturation temperature is higher than 0 °C and lower than or equal to 10 °C so as to reduce the temperature difference between the saturation temperature and the frost temperature. Thus, the subcooling (degree of subcooling) of refrigerant at the outlet of the outdoor heat exchanger 13 to be defrosted is as small as about 5 K. Thus, a small amount of refrigerant is necessary for defrosting, and a shortage of refrigerant circulating in the main refrigerant circuit can be avoided.

[0143] In addition, an area of two-phase gas-liquid is increased for refrigerant in the heat transfer tube of the outdoor heat exchanger 13 to be defrosted, an area where the temperature difference between the saturation temperature and the frost temperature is uniform, and the amount of defrosting in the entire heat exchangers can be uniformized.

[0144] In the air-conditioning apparatus 100 of this embodiment, refrigerant that has flowed out of the outdoor heat exchanger 13 to be defrosted flows into the other outdoor heat exchanger 13 serving as an evaporator. Thus, the evaporative capacity in the refrigeration cycle is maintained, and a decrease in the suction pressure can be suppressed. In addition, liquid back to the compressor 11 can be prevented.

[0145] Furthermore, the flow rate control of the reducing device 18 can change the defrosting capacity. Thus, the increase in the flow rate of the reducing device 18 as the outdoor-air temperature decreases, can uniformize the time for defrosting.

[0146] In the air-conditioning apparatus 100 of this embodiment, the time necessary for defrosting can be uniformized by changing a criterion for determining whether to perform a heating defrosting operation or not based on the outdoor-air temperature, for example. In addition, since the heating defrosting operation and the heating-stop defrosting operation can be selectively performed based on the outdoor-air temperature, efficient defrosting can be selectively performed. Furthermore, since output power of the outdoor fan 21 is changed based on the outdoor-air temperature, the amount of heat transferred to the outdoor air from refrigerant for defrosting can be reduced.

Embodiment 2

[0147] FIG. 16 illustrates a configuration of an air-conditioning apparatus 101 according to Embodiment 2 of the present invention. In FIG. 16, devices designated by the same reference characters, for example, perform similar operations, for example, to those described in Embodiment 1. Part of the configuration of the air-conditioning apparatus 101 different from that of the air-conditioning apparatus 100 of the Embodiment 1 will be hereinafter mainly described.

[0148] The air-conditioning apparatus 101 according to Embodiment 2 includes a third flow rate control device 15c and a refrigerant-to-refrigerant heat exchanger 28 (hereinafter referred to as a refrigerant-refrigerant heat exchanger 28) in addition to the configuration of the air-conditioning apparatus 100 of Embodiment 1. The third flow rate control device 15c is disposed in a pipe connecting a first connection pipe 24a and a first connection pipe 24b for bypassing.

[0149] The third flow rate control device 15c is constituted by, for example, a valve having a variable opening degree, such as an electronically controlled expansion valve. The third flow rate control device 15c of this Embodiment corresponds to a "third pressure adjustment device" of the present invention. Thus, although the air-conditioning apparatus 101 illustrated in FIG. 16 includes the second flow rate control devices 15a and 15b, the second flow rate control devices 15a and 15b are not necessarily provided.

[0150] FIG. 17 is a table showing states of ON/OFF (opening/closing) or opening degree adjustment of devices (valves) having valves in operations of the air-conditioning apparatus 101 according to Embodiment 2 of the present invention. Operations of the second flow rate control devices 15a and 15b and the third flow rate control device 15c in the air-conditioning apparatus 101 of this Embodiment are different from those in Embodiment 1.

[0151] In a heating defrosting operation, the third flow rate control device 15c causes refrigerant that has flowed from an outdoor heat exchanger 13 to be defrosted to flow into a part upstream of an outdoor heat exchanger 13 serving as an evaporator. The third flow rate control device 15c is controlled by a control device 60 in such a manner that a pressure of the outdoor heat exchanger 13 to be defrosted is a medium pressure higher than 0 °C and lower than or equal to 10 °C.

[0152] On the other hand, the second flow rate control device 15a or 15b, which controls the pressure of the outdoor heat exchanger 13 to be defrosted in Embodiment 1, is closed. The second flow rate control device 15a or 15b, which is fully open in Embodiment 1, is controlled to have an opening degree with which the saturation temperature at an intermediate pressure of, for example, a second extension pipe 50 is about 0 °C to 20 °C.

[0153] FIG. 18 is a view showing a flow of refrigerant in a heating defrosting operation of the air-conditioning apparatus 101 according to Embodiment 2 of the present invention. In FIG. 18, bold lines represent sections where refrigerant flows in the heating defrosting operation, and thin lines represent sections where refrigerant does not flow.

[0154] FIG. 19 is a P-h diagram in the heating defrosting operation of the air-conditioning apparatus 101 according to Embodiment 2 of the present invention. In FIG. 19, point (a) to point (i) represent the states of refrigerant at points denoted by the same characters in FIG. 18.

[0155] If it is determined that defrosting for eliminating frost accumulation is necessary in a heating normal operation, the control device 60 closes a first solenoid valve 16b and a second flow rate control device 15b corresponding to the

outdoor heat exchanger 13b to be defrosted. The control device 60 opens a second solenoid valve 17b and a third solenoid valve 19b and sets the opening degrees of the reducing device 18 and the reducing device 20 at predetermined opening degrees. The control device 60 sets the opening degree of the third flow rate control device 15c at a predetermined opening degree.

[0156] In this manner, a refrigerant path (first refrigerant path) passing through a compressor 11, a reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, and the third flow rate control device 15c in this order is formed.

[0157] A refrigerant path (medium-pressure defrosting circuit, second refrigerant path) serving as an injection part and passing through the compressor 11, the reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the third solenoid valve 19b, the refrigerant-refrigerant heat exchanger 28, the reducing device 20, and the compressor 11 in this order is also formed. Then, a heating defrosting operation starts.

[0158] When the heating defrosting operation starts, part of high-temperature high-pressure gas refrigerant discharged from the compressor 11 flows into a first defrosting pipe 26 and has its pressure reduced to a medium pressure in the reducing device 18. The change of refrigerant at this time is represented by a line from point (b) to point (f) in FIG. 19.

[0159] The refrigerant whose pressure has been reduced to the medium pressure represented by point (f) in FIG. 19 passes through the second solenoid valve 17b and the second connection pipe 25b, and flows into the outdoor heat exchanger 13b. The refrigerant that has flowed into the outdoor heat exchanger 13b is cooled through heat exchange with frost accumulated on the outdoor heat exchanger 13b.

[0160] The change of refrigerant at this time is represented by a change from point (f) to point (g) in FIG. 19. Here, refrigerant for defrosting is at a saturation temperature higher than or equal to frost temperature (0 °C) and lower than or equal to 10 °C.

[0161] The refrigerant used for defrosting the outdoor heat exchanger 13b is branched into two refrigerant parts. One of the two refrigerant parts passes through the third flow rate control device 15c and flows into the main refrigerant circuit from the first connection pipe 24a between the second flow rate control device 15a and the outdoor heat exchanger 13a (point (e)). This refrigerant flows into the outdoor heat exchanger 13a serving as an evaporator and evaporates.

[0162] The other refrigerant part passes through the third solenoid valve 19b, and exchanges heat, in the refrigerant-refrigerant heat exchanger 28, with refrigerant for heating flowing at an intermediate pressure at which a saturation temperature is higher than that at a medium pressure represented by point (f).

[0163] The refrigerant heated by the heat exchange has its pressure reduced to an injection pressure in the reducing device 20 (point (i)). At this time, refrigerant for heating is cooled through heat exchange. The change of refrigerant at this time is represented by a change from point (d) to point (h) in FIG. 19.

[0164] As described above, in the air-conditioning apparatus 101 according to Embodiment 2, refrigerant that has passed through the outdoor heat exchanger 13 to be defrosted flows under a low pressure (corresponding to a suction pressure of the compressor 11).

[0165] Thus, the control device 60 can perform control for the intermediate pressure (point (d)) and control of the medium pressure (point (f)), separately from each other. Since the intermediate pressure may be higher than the medium pressure, valves having small Cv values can be used as the second flow rate control devices 15a and 15b.

[0166] In a case where the intermediate pressure is higher than the medium pressure, refrigerant to be injected into the compressor 11 after having passed through the outdoor heat exchanger 13 to be defrosted exchanges heat, in the refrigerant-refrigerant heat exchanger 28, with refrigerant at the intermediate pressure that has returned from the indoor units 30a and 30b to the outdoor unit 10 so that the refrigerant to be injected is heated and refrigerant flowing in the main refrigerant circuit is cooled (subcooled).

[0167] Thus, in the outdoor heat exchanger 13 serving as an evaporator, an enthalpy difference can be increased, and the amount of heat absorption from the outdoor air can be increased, thereby enhancing the heating capacity. In this aspect, in the air-conditioning apparatus 100 of Embodiment 1 described above, since refrigerant that has passed through the outdoor heat exchanger 13 to be defrosted returns to the mainstream, the intermediate pressure (pressure of the second extension pipe 50) needs to be made lower than the medium pressure (pressure of refrigerant flowing into the outdoor heat exchanger 13 to be defrosted).

Embodiment 3

[0168] FIG. 20 illustrates a configuration of an air-conditioning apparatus 102 according to Embodiment 3 of the present invention. In FIG. 20, devices designated by the same reference characters as those in Figs. 1 and 16, for example, perform similar operations, for example, to those described in Embodiment 1 or 2. Thus, part of the configuration of the air-conditioning apparatus 102 of this Embodiment different from that of the air-conditioning apparatus 101 of the Embodiment 2 will be hereinafter mainly described.

[0169] In addition to the configuration of the air-conditioning apparatus 101 of Embodiment 2 described above, the air-conditioning apparatus 102 according to Embodiment 3 includes a fourth flow rate control device 29 for performing

pressure adjustment in such a manner that refrigerant flows from a pipe (pipe between a second extension pipe 50 and second flow rate control devices 15a and 15b) at an intermediate pressure in a main refrigerant circuit to a part upstream of a refrigerant-refrigerant heat exchanger 28 of a second defrosting pipe 27.

[0170] In Embodiment 3, a third flow rate control device 15c also corresponds to a "third reducing device" of the present invention. The fourth flow rate control device 29 corresponds to a "fourth pressure adjustment device" of the present invention.

[0171] In a manner similar to Embodiment 2, in a heating defrosting operation of Embodiment 3, a refrigerant path (first refrigerant path) passing through a compressor 11, a reducing device 18, a second solenoid valve 17b, an outdoor heat exchanger 13b, and the third flow rate control device 15c in this order is formed.

[0172] A refrigerant path (medium-pressure defrosting circuit, second refrigerant path) serving as an injection part (port) and passing through the compressor 11, the reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the third solenoid valve 19b, the refrigerant-refrigerant heat exchanger 28, the reducing device 20, and the compressor 11 in this order is also formed.

[0173] In the heating defrosting operation of Embodiment 3, the third flow rate control device 15c and the fourth flow rate control device 29 control a medium pressure. Specifically, in a case where the third flow rate control device 15c is fully closed in controlling the medium pressure with a low flow rate of refrigerant for defrosting, the control device 60 adjusts the opening degree of the fourth flow rate control device 29 so as to increase the medium pressure.

[0174] Refrigerant that has passed through the third solenoid valve 19b exchanges heat with refrigerant for heating in the refrigerant-refrigerant heat exchanger 28, in a manner similar to Embodiment 2. Then, the degree of subcooling of refrigerant for heating is increased, and the amount of heat absorption in the outdoor heat exchanger 13 serving as an evaporator is increased, thereby enhancing the heating capacity.

[0175] As described above, in the air-conditioning apparatus 102 of Embodiment 3, the fourth flow rate control device 29 is made open even in a case where the flow rate of refrigerant for defrosting is low so that refrigerant at a medium pressure subjected to pressure adjustment is caused to flow into the outdoor heat exchanger 13 to be defrosted, and thereby, medium pressure control on the outdoor heat exchanger 13 to be defrosted can be stably performed.

[0176] In addition, heat exchange in the refrigerant-refrigerant heat exchanger 28 can increase the degree of subcooling of refrigerant for heating. Thus, the amount of heat absorption from outdoor air can be increased in the outdoor heat exchanger 13 serving as an evaporator, thereby enhancing the heating capacity.

Embodiment 4

[0177] FIG. 21 illustrates a configuration of an air-conditioning apparatus 103 according to Embodiment 4 of the present invention. In FIG. 21, devices designated by the same reference characters as those in FIG. 20, for example, perform similar operations, for example, to those described in Embodiments 1 to 3. Part of the configuration of the air-conditioning apparatus 103 of this Embodiment different from that of the air-conditioning apparatus 102 of the Embodiment 3 will be hereinafter mainly described.

[0178] In the air-conditioning apparatus 103 according to Embodiment 4, one end of a first defrosting pipe 26 is connected to first connection pipes 24a and 24b, instead of the configuration of the air-conditioning apparatus 102 of Embodiment 3. In addition, one end of the second defrosting pipe 27 is connected to second connection pipes 25a and 25b.

[0179] The air-conditioning apparatus 102 of Embodiment 3 includes the third flow rate control device for connecting the first connection pipes 24a and 24b for bypassing. Alternatively, the air-conditioning apparatus 103 of this Embodiment includes a third flow rate control device 15c and check valves 70a and 70b in such a manner that refrigerant used for defrosting passes through the second defrosting pipe 27 and a third defrosting pipe 71 and flows toward a first connection pipe 24a or 24b.

[0180] A third flow rate control device 15c of an air-conditioning apparatus 104 and a fourth flow rate control device 29 of the air-conditioning apparatus 103 in Embodiment 4 respectively correspond to a "third reducing device" and a "fourth reducing device" of the present invention.

[0181] FIG. 22 illustrates a configuration of the air-conditioning apparatus 104 according to Embodiment 4 of the present invention. In the air-conditioning apparatus 104 illustrated in FIG. 22, the third flow rate control device 15c and the check valves 70a and 70b of the air-conditioning apparatus 103 are omitted.

[0182] In the configurations illustrated in Figs. 21 and 22, refrigerant in the outdoor heat exchangers 13 of the air-conditioning apparatuses 103 and 104 of this Embodiment flows in a reverse direction to the flow of refrigerant in the air-conditioning apparatuses 100 to 102 of Embodiments 1 to 3.

[0183] If it is determined that defrosting for eliminating frost accumulation is necessary in a normal heating operation, the control device 60 closes a first solenoid valve 16b corresponding to an outdoor heat exchanger 13b to be defrosted and fully closes a second flow rate control device 15b.

[0184] The control device 60 opens a second solenoid valve 17b and a third solenoid valve 19b and adjusts the opening degree of the reducing device 18 to a predetermined opening degree. The control device 60 opens the third flow rate

control device 15c in the air-conditioning apparatus 104 and opens the fourth flow rate control device 29 in the air-conditioning apparatus 103.

[0185] In this manner, in the air-conditioning apparatus 103, a refrigerant path (first refrigerant path) passing through a compressor 11, the reducing device 18, the second solenoid valve 17b, an outdoor heat exchanger 13b, the third solenoid valve 19b, the third flow rate control device 15c, and the first connection pipe 24a in this order is formed.

[0186] In the air-conditioning apparatus 104, a refrigerant path (first refrigerant path) passing through the compressor 11, the reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the third solenoid valve 19b, the fourth flow rate control device 29, the refrigerant heat exchanger 28, the second flow rate control device 15a, and the first connection pipe 24a in this order is also formed.

[0187] As a second path, a refrigerant path (medium-pressure defrosting circuit, second refrigerant path) serving as an injection part (port) and passing through the compressor 11, the reducing device 18, the second solenoid valve 17b, the outdoor heat exchanger 13b, the third solenoid valve 19b, the refrigerant heat exchanger 28, the reducing device 20, and the compressor 11 in this order is formed. Then, a heating defrosting operation starts.

[0188] In the heating defrosting operation, the control device 60 controls the opening degree of the third flow rate control device 15c or the fourth flow rate control device 29 in such a manner that the pressure (medium pressure) of an outdoor heat exchanger 13b to be defrosted is higher than 0 °C and lower than or equal to 10 °C, in terms of saturation temperature.

[0189] The reducing device 20 has an opening degree at which refrigerant can be injected into the compressor 11 until the discharge superheat reaches about 10 K to 20 K, for example, so as to control the discharge temperature and discharge superheat of the compressor 11, for example.

[0190] As illustrated in FIG. 2, the first connection pipes 24a and 24b are connected to the heat transfer tubes 5a upstream of the outdoor heat exchangers 13a and 13b in the air flow direction. The heat transfer tubes 5a of the outdoor heat exchangers 13a and 13b are arranged in a plurality of columns in the air flow direction and refrigerant sequentially flows toward downstream rows.

[0191] Thus, refrigerant supplied to the outdoor heat exchanger 13b to be defrosted flows from the heat transfer tubes 5a upstream in the air flow direction to the downstream side, and parallel flows in which the refrigerant flow direction coincides with the air flow direction are obtained.

[0192] As described above, in the outdoor heat exchanger 13 to be defrosted according to Embodiment 4, the refrigerant flow direction can be made coincide with the air flow direction. The parallel flow of refrigerant allows heat transferred to the air in defrosting to be used for defrosting of frost on the downstream fins 5b. Thus, the efficiency of defrosting can be increased.

Embodiment 5

[0193] In Embodiments 1 to 4, the outdoor heat exchangers 13 are divided into two outdoor heat exchangers 13a and 13b. However, the present invention is not limited to this example. In a configuration including three or more outdoor heat exchangers, application of the above-described inventive concept allows some of the outdoor heat exchangers 13 to be defrosted with other outdoor heat exchangers 13 continuing a heating operation.

[0194] In Embodiments 1 to 4, one outdoor heat exchanger is divided into a plurality of outdoor heat exchangers 13. However, the present invention is not limited to this example. In a configuration including separate outdoor heat exchangers 13 that are connected in parallel, application of the above-described inventive concept allows part of the outdoor heat exchangers 13 to be defrosted and another part of the outdoor heat exchangers 13 to continue a heating operation.

List of Reference Signs

[0195]

5a	heat transmission pipe
5b	fin
10	outdoor unit
11	compressor
12	cooling/heating switching device
13, 13a, 13b	outdoor heat exchanger
14	accumulator
15a, 15b	second flow rate control device
15c	third flow rate control device
16, 16a, 16b	first solenoid valve

17, 17a, 17b	second solenoid valve
18, 20	reducing device
19, 19a, 19b	third solenoid valve
21	outdoor fan
5 22	discharge pipe
23	suction pipe
24, 24a, 24b	first connection pipe
25, 25a, 25b	second connection pipe
26	first defrosting pipe
10 27	second defrosting pipe
28	refrigerant-refrigerant heat exchanger
29	fourth flow rate control device
30, 30a, 30b	indoor unit
31, 31a, 31b	indoor heat exchanger
15 32, 32a, 32b	first flow rate control device
40, 41a, 41b	first extension pipe
50, 51a, 51b	second extension pipe
60	control device
70a, 70b	check valve
20 71	third defrosting pipe
100, 101, 102	air-conditioning apparatus
103, 104	air-conditioning apparatus.

25 Claims

1. An air-conditioning apparatus comprising:

30 a compressor to allow refrigerant to be injected into a portion thereof located intermediate of a compression stroke, suck refrigerant having a low pressure, compress refrigerant, and discharge refrigerant having a high temperature;
 an indoor heat exchanger to exchange heat between air to be conditioned and the refrigerant;
 a first flow rate control device to adjust and control a flow rate of the refrigerant passing through the indoor heat exchanger;
 35 a plurality of outdoor heat exchangers connected in parallel to exchange heat between outdoor air and the refrigerant,
 the compressor, the indoor heat exchanger, the first flow rate control device, and the plurality of outdoor heat exchangers being connected by pipes to form a main refrigerant circuit in which the refrigerant circulates;
 40 a first defrosting pipe to allow a branched part of refrigerant discharged from the compressor to pass therethrough and flow into at least one of the outdoor heat exchangers to be defrosted;
 a first pressure adjustment device to adjust a pressure of refrigerant passing through the first defrosting pipe to a medium pressure higher than the low pressure and lower than the high pressure;
 a second defrosting pipe to allow refrigerant that has passed through the at least one of the outdoor heat exchangers to be defrosted to pass therethrough to be injected into the compressor; and
 45 a second pressure adjustment device to adjust a pressure of refrigerant passing through the second defrosting pipe to an injection pressure.

2. The air-conditioning apparatus of claim 1,
 being configured to perform defrosting and heating by causing at least one of the outdoor heat exchangers other
 50 than at least one of the outdoor heat exchangers to be defrosted to serve as an evaporator.

3. The air-conditioning apparatus of claim 2,
 further comprising a third pressure adjustment device to adjust a pressure of refrigerant that has flowed out of the
 at least one of the outdoor heat exchangers to be defrosted and cause the refrigerant to flow into upstream of the
 55 outdoor heat exchanger, serving as the evaporator, in the main refrigerant circuit.

4. The air-conditioning apparatus of claim 3,
 further comprising a refrigerant-refrigerant heat exchanger to exchange heat between refrigerant flowing in the main

refrigerant circuit to flow into at least one of the outdoor heat exchangers serving as the evaporator and refrigerant flowing in the second defrosting pipe.

5 5. The air-conditioning apparatus of any one of claims 1 to 4,
further comprising a fourth pressure adjustment device to adjust a pressure of refrigerant flowing in the main refrigerant circuit and cause the refrigerant to flow into the second defrosting pipe.

10 6. The air-conditioning apparatus of any one of claims 1 to 5,
wherein the outdoor heat exchanger includes

- a plurality of heat transfer tubes to allow refrigerant to pass therethrough, the plurality of heat transfer tubes arranged in a plurality of levels extending perpendicularly to direction of passage of air and in a plurality of columns extending in parallel with the direction of passage of air, and
- 15 - a plurality of fins spaced from one another so that air passes therethrough in the direction of passage of air,
- a pipe connected to the heat transfer tubes in a column upstream in the direction of passage of air is connected to the first defrosting pipe, and
- a pipe connected to the heat transfer tubes in a column downstream in the direction of passage of air is connected to the second defrosting pipe.

20 7. The air-conditioning apparatus of any one of claims 3 to 6,
wherein the third pressure adjustment device is configured to control a pressure of refrigerant flowing out of at least one of the outdoor heat exchangers to be defrosted.

25 8. The air-conditioning apparatus of claim 7,
wherein the third pressure adjustment device is configured to control the pressure of refrigerant flowing out of the at least one of the outdoor heat exchangers to be defrosted to have a pressure corresponding to a saturation temperature of higher than 0 °C and lower than or equal to 10 °C.

30 9. The air-conditioning apparatus of any one of claims 1 to 8,
being configured to control a discharge temperature or a discharge superheat of refrigerant discharged from the compressor by adjustment of pressure by the second pressure adjustment device.

35 10. The air-conditioning apparatus of any one of claims 1 to 9,
further comprising an outdoor-air temperature detector to detect an outdoor-air temperature of air outside a space to be air-conditioned, wherein
the first pressure adjustment device is configured to perform a flow rate control based on the outdoor-air temperature.

40 11. The air-conditioning apparatus of any one of claims 1 to 10,
further comprising an outdoor-air temperature detector to detect an outdoor-air temperature of air outside a space to be air-conditioned, the air-conditioning apparatus being configured to change a criterion for determining whether to start a defrosting operation, based on the outdoor-air temperature.

45 12. The air-conditioning apparatus of any one of claims 1 to 11,
further comprising an outdoor-air temperature detector to detect an outdoor-air temperature of air outside a space to be air-conditioned, the air-conditioning apparatus being configured to select, based on the outdoor-air temperature, from a heating-and-defrosting operation mode in which at least one of the outdoor heat exchangers to be defrosted is selected and defrosted and another one of the outdoor heat exchangers serves as an evaporator so as to continue heating, and a heating-stop defrosting operation mode in which all the outdoor heat exchangers are defrosted.

50 13. The air-conditioning apparatus of any one of claims 1 to 12,
further comprising
an outdoor-air temperature detector to detect an outdoor-air temperature of air outside a space to be air-conditioned, and
an outdoor fan to blow the outdoor air to the plurality of outdoor heat exchangers, the air-conditioning apparatus
55 being configured to change, based on the outdoor-air temperature, output power of the outdoor fan in defrosting the at least one of the outdoor heat exchangers to be defrosted.

14. The air-conditioning apparatus of any one of claims 1 to 13,

being configured to defrost each of the plurality of outdoor heat exchangers at least once in the defrosting operation mode.

5

10

15

20

25

30

35

40

45

50

55

FIG. 1

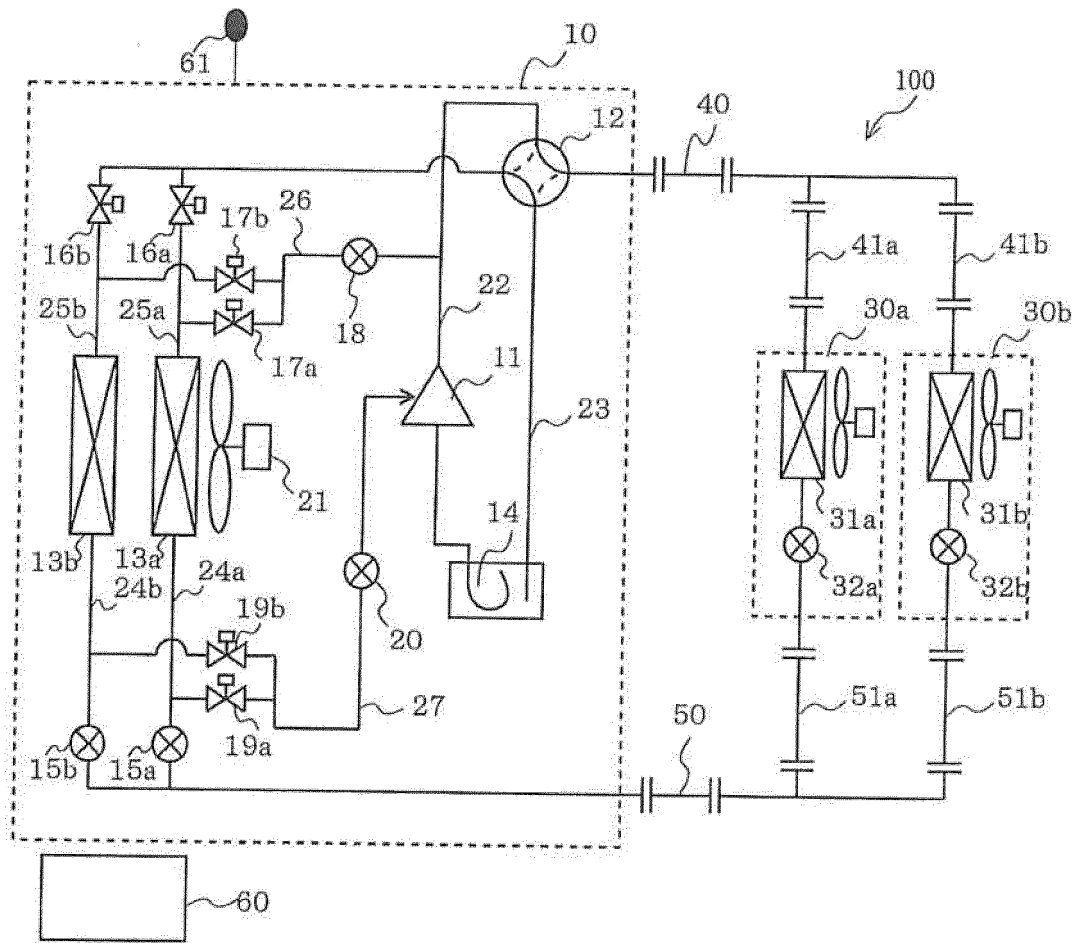


FIG. 2

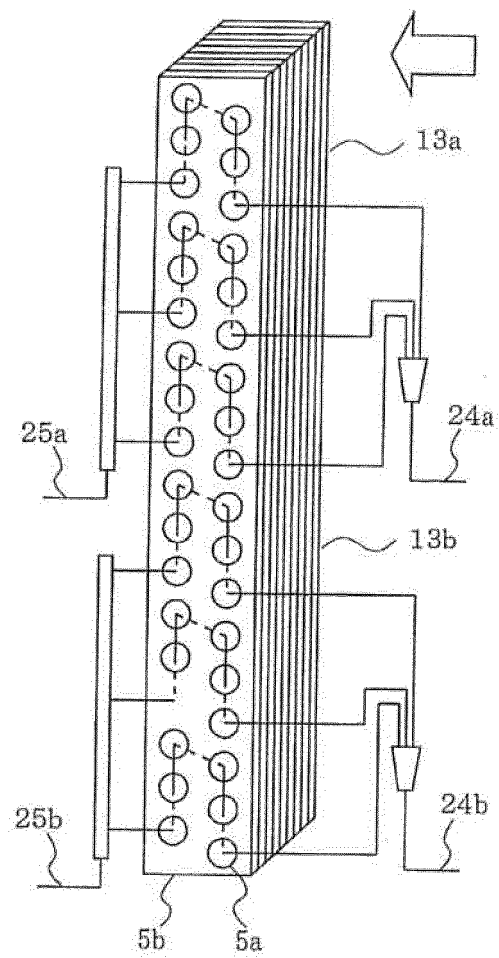


FIG. 3

VALVE NUMBER	COOLING	HEATING		
		NORMAL OPERATION	CONTINUOUS HEATING	
			13a: EVAPORATOR 13b: DEFROSTING	13a: DEFROSTING 13b: EVAPORATOR
1 2	OFF	ON	ON	ON
32a, 32b	INDOOR UNIT OUTLET REFRIGERANT SUPERHEATED	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL
1 5 a	FULLY OPEN	FULLY OPEN	FULLY OPEN	DEFROSTING HEAT EXCHANGER PRESSURE
1 5 b	FULLY OPEN	FULLY OPEN	DEFROSTING HEAT EXCHANGER PRESSURE	FULLY OPEN
1 6 a	ON	ON	ON	OFF
1 6 b	ON	ON	OFF	ON
1 7 a	OFF	OFF	OFF	ON
1 7 b	OFF	OFF	ON	OFF
1 8	CLOSED	CLOSED	FIXED OPENING DEGREE	FIXED OPENING DEGREE
1 9 a	OFF	OFF	OFF	ON
1 9 b	OFF	OFF	ON	OFF
2 0	CLOSED	CLOSED	DISCHARGE TEMPERATURE (DISCHARGE SUPERHEAT)	DISCHARGE TEMPERATURE (DISCHARGE SUPERHEAT)

FIG. 4

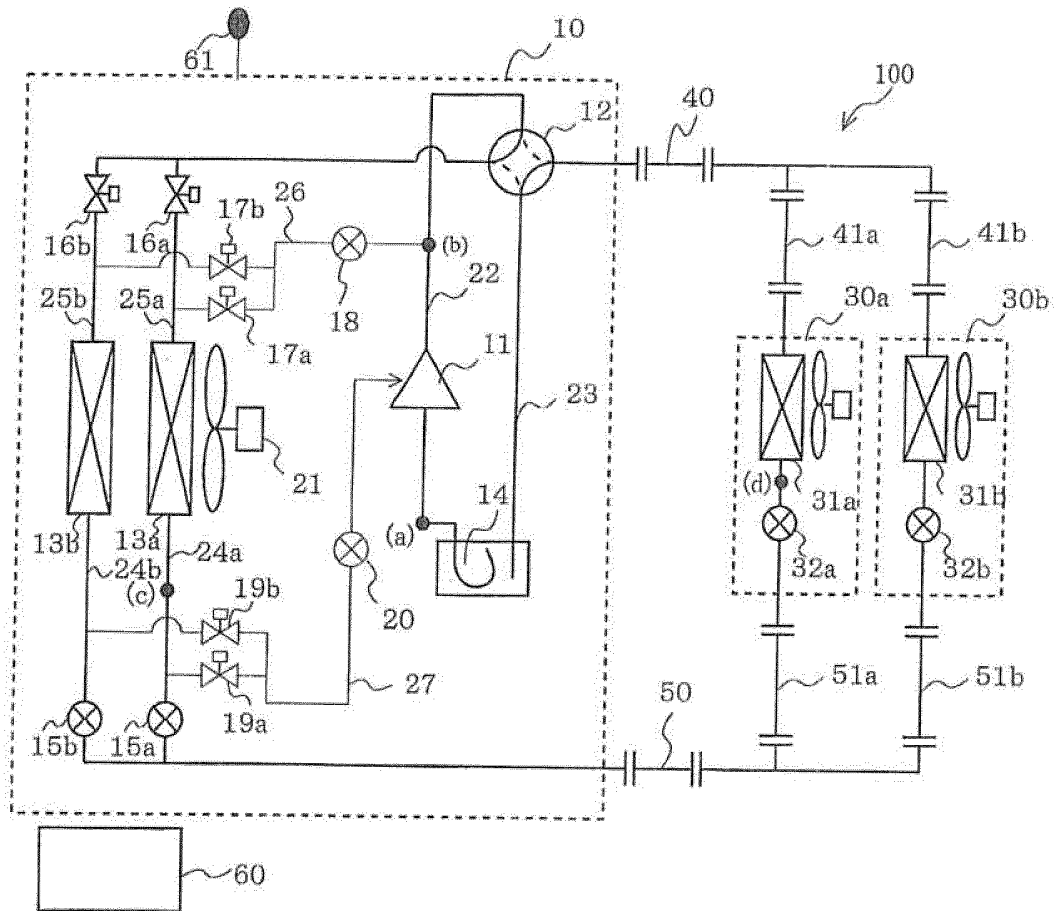


FIG. 5

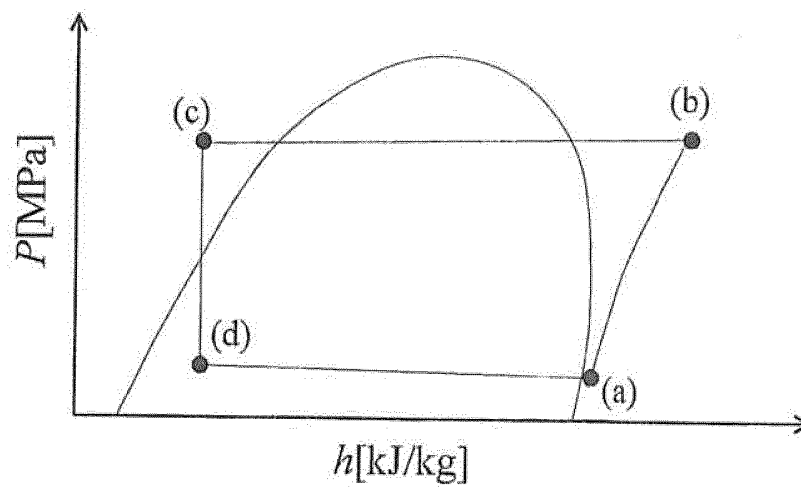


FIG. 6

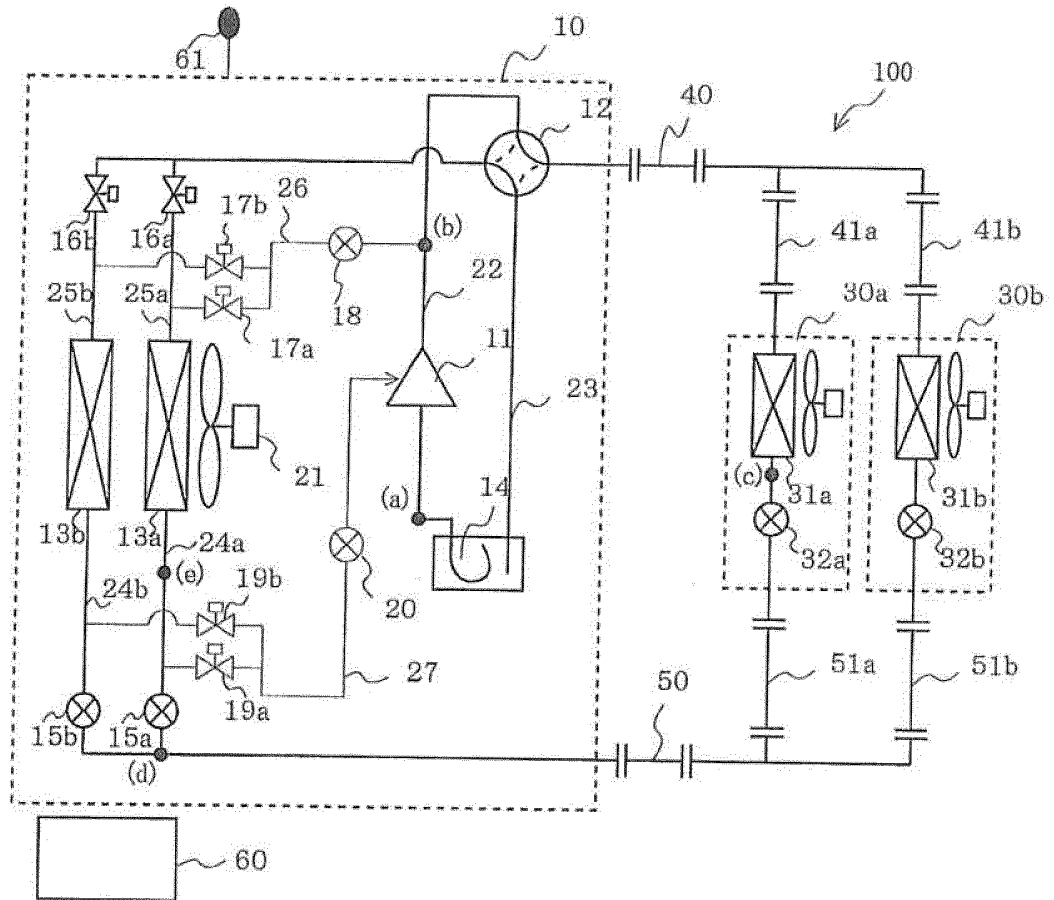


FIG. 7

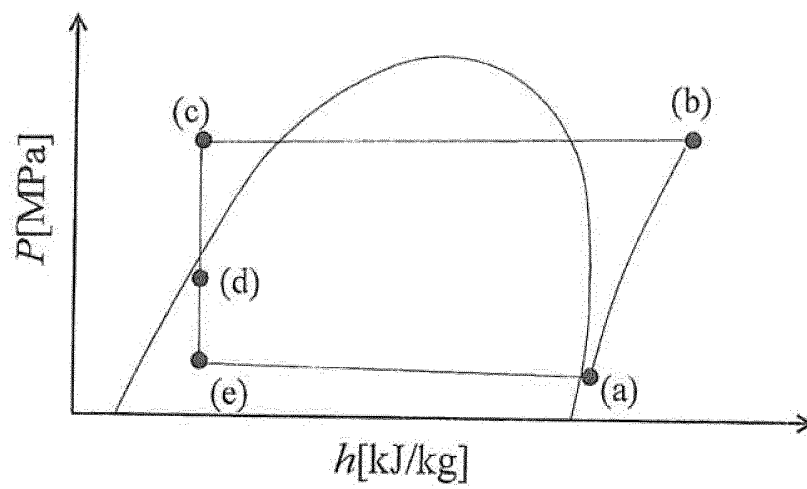


FIG. 8

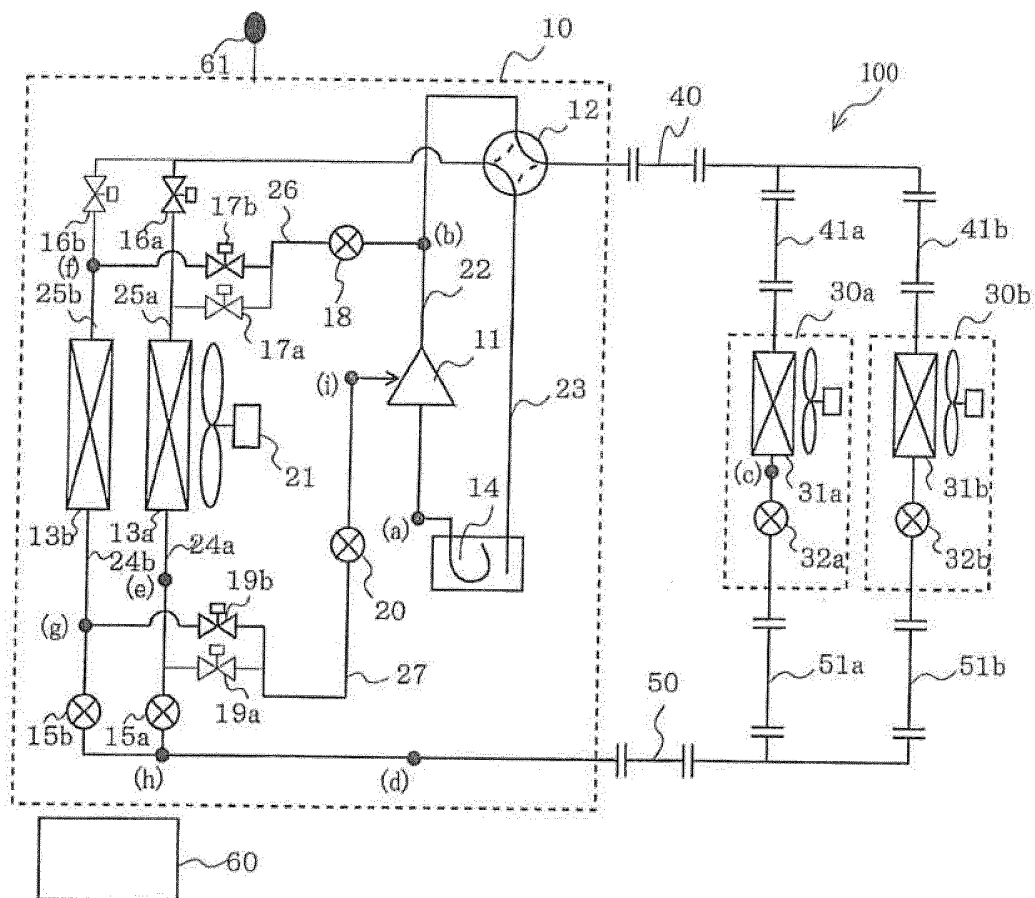


FIG. 9

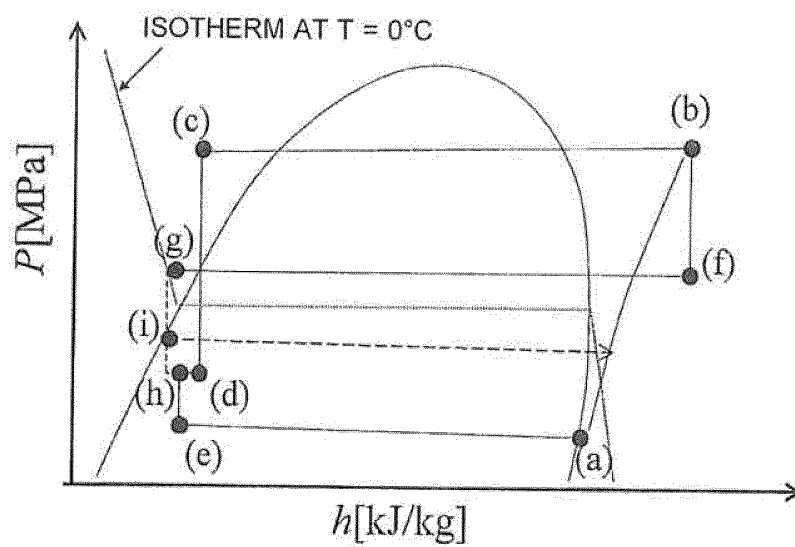


FIG. 10

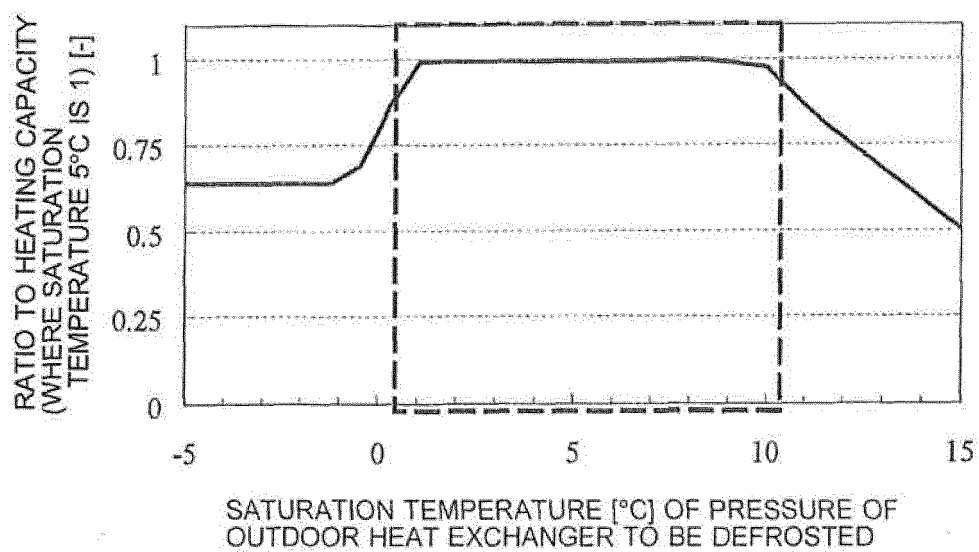


FIG. 11

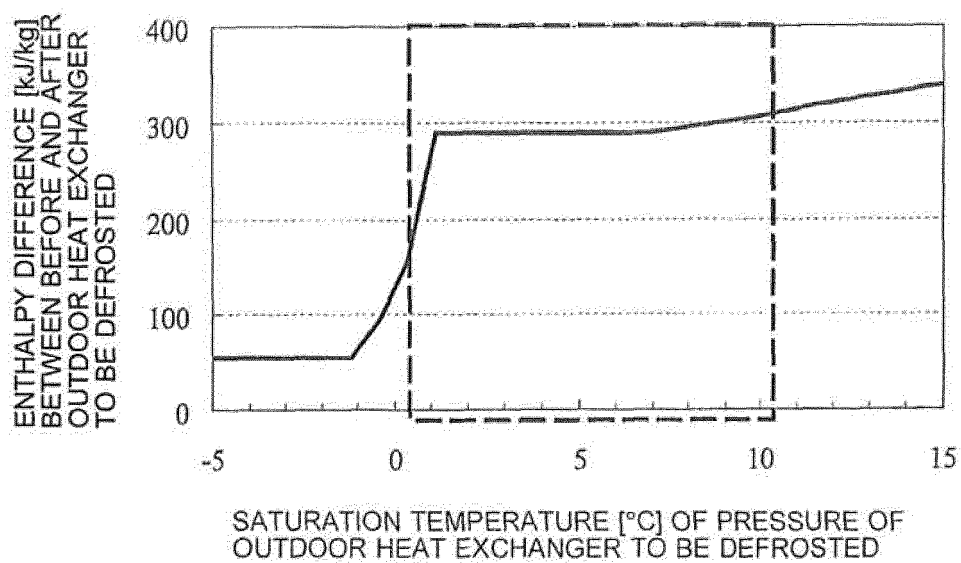


FIG. 12

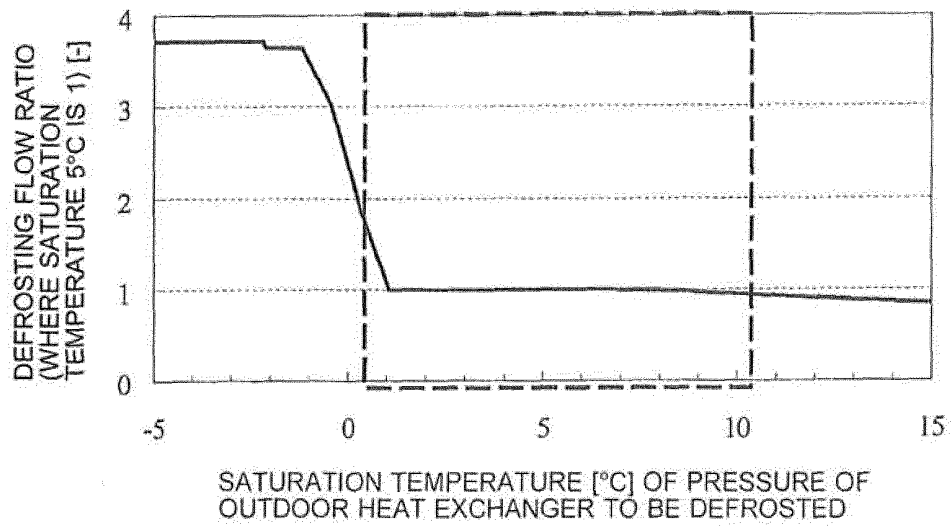


FIG. 13

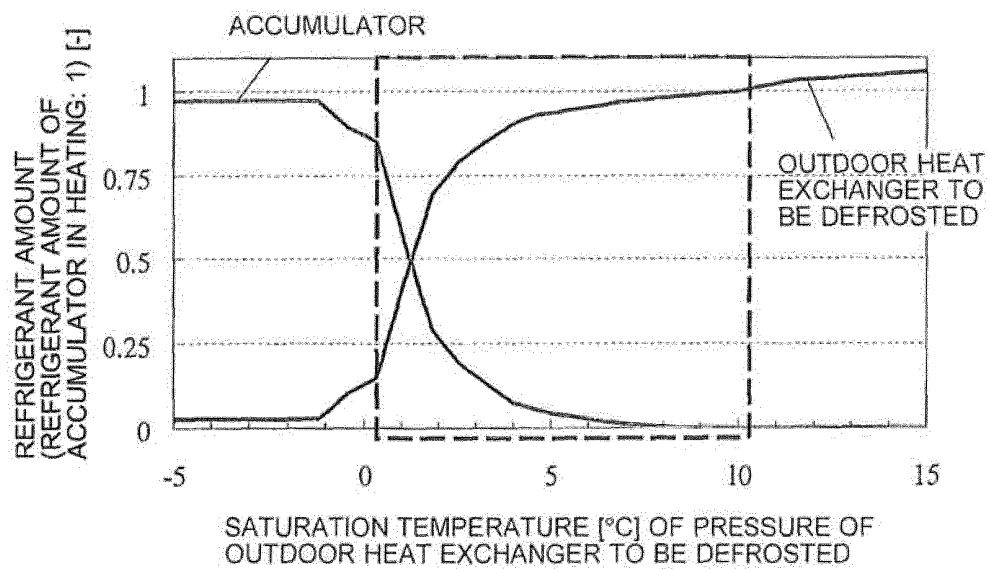


FIG. 14

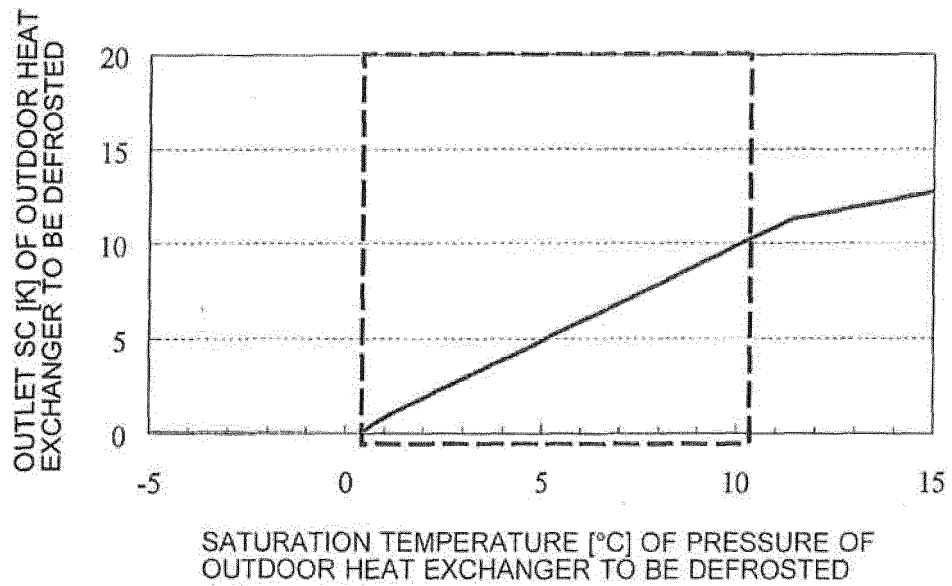


FIG. 15

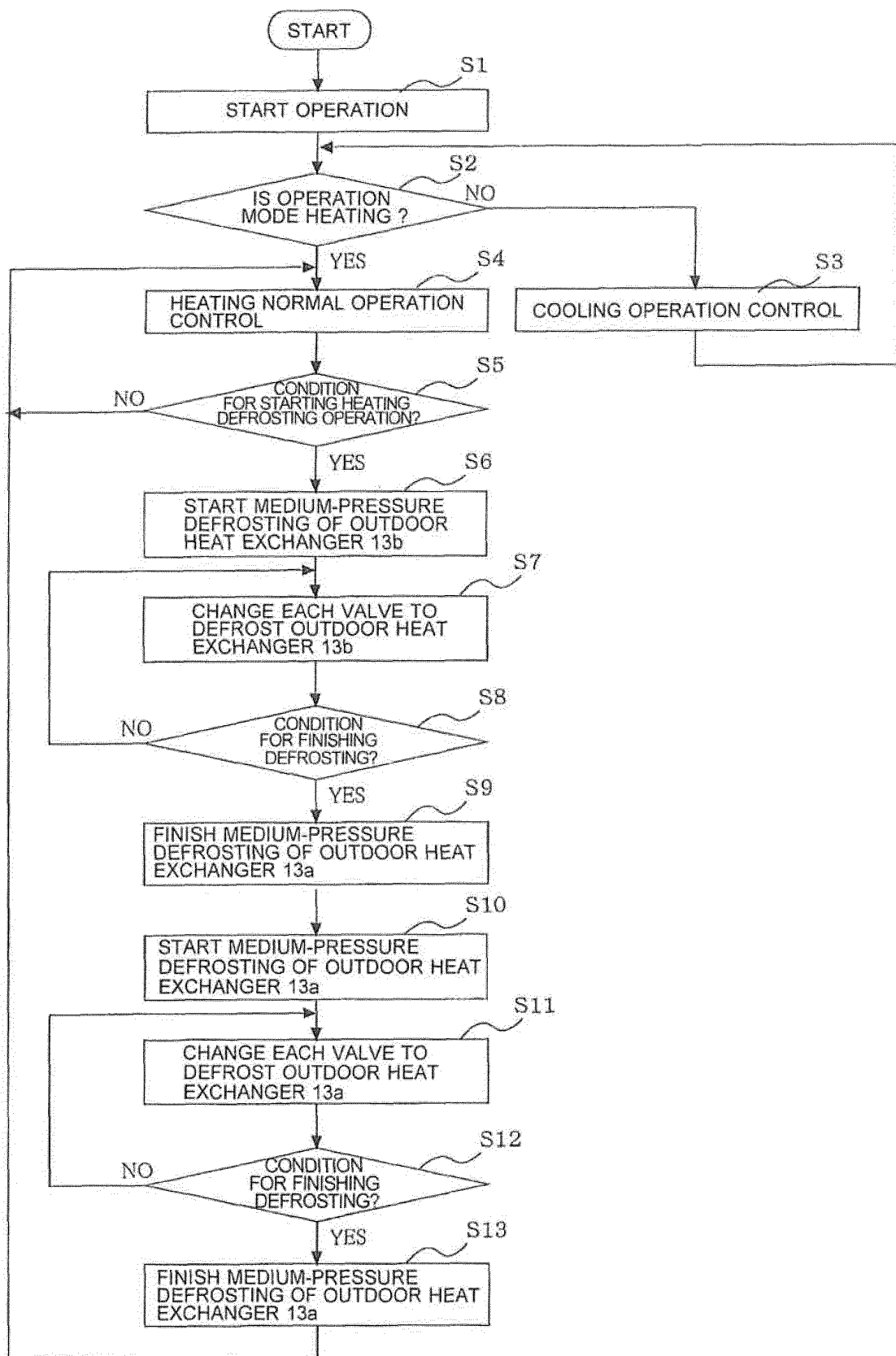


FIG. 16

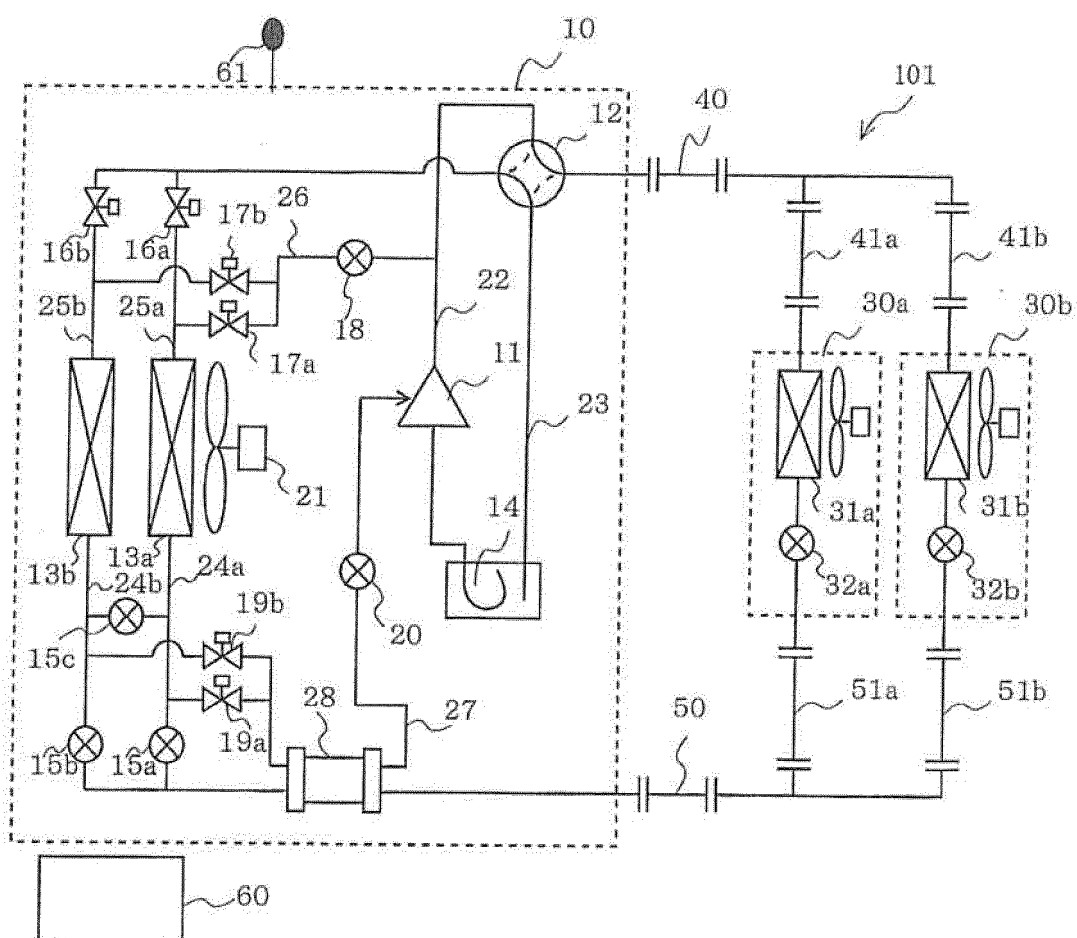


FIG. 17

VALVE NUMBER	COOLING	HEATING		
		NORMAL OPERATION	CONTINUOUS HEATING	
			13a: EVAPORATOR 13b: DEFROSTING	13a: DEFROSTING 13b: EVAPORATOR
1 2	OFF	ON	ON	ON
32a, 32b	INDOOR UNIT OUTLET REFRIGERANT SUPERHEATED	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL	INDOOR UNIT OUTLET REFRIGERANT SUBCOOL
1 5 a	FULLY OPEN	FULLY OPEN	INTERMEDIATE PRESSURE	CLOSED
1 5 b	FULLY OPEN	FULLY OPEN	CLOSED	INTERMEDIATE PRESSURE
1 5 c	FULLY OPEN	FULLY OPEN	DEFROSTING HEAT EXCHANGER PRESSURE	DEFROSTING HEAT EXCHANGER PRESSURE
1 6 a	ON	ON	ON	OFF
1 6 b	ON	ON	OFF	ON
1 7 a	OFF	OFF	OFF	ON
1 7 b	OFF	OFF	ON	OFF
1 8	CLOSED	CLOSED	FIXED OPENING DEGREE	FIXED OPENING DEGREE
1 9 a	OFF	OFF	OFF	ON
1 9 b	OFF	OFF	ON	OFF
2 0	CLOSED	CLOSED	DISCHARGE TEMPERATURE (DISCHARGE SUPERHEAT)	DISCHARGE TEMPERATURE (DISCHARGE SUPERHEAT)

FIG. 18

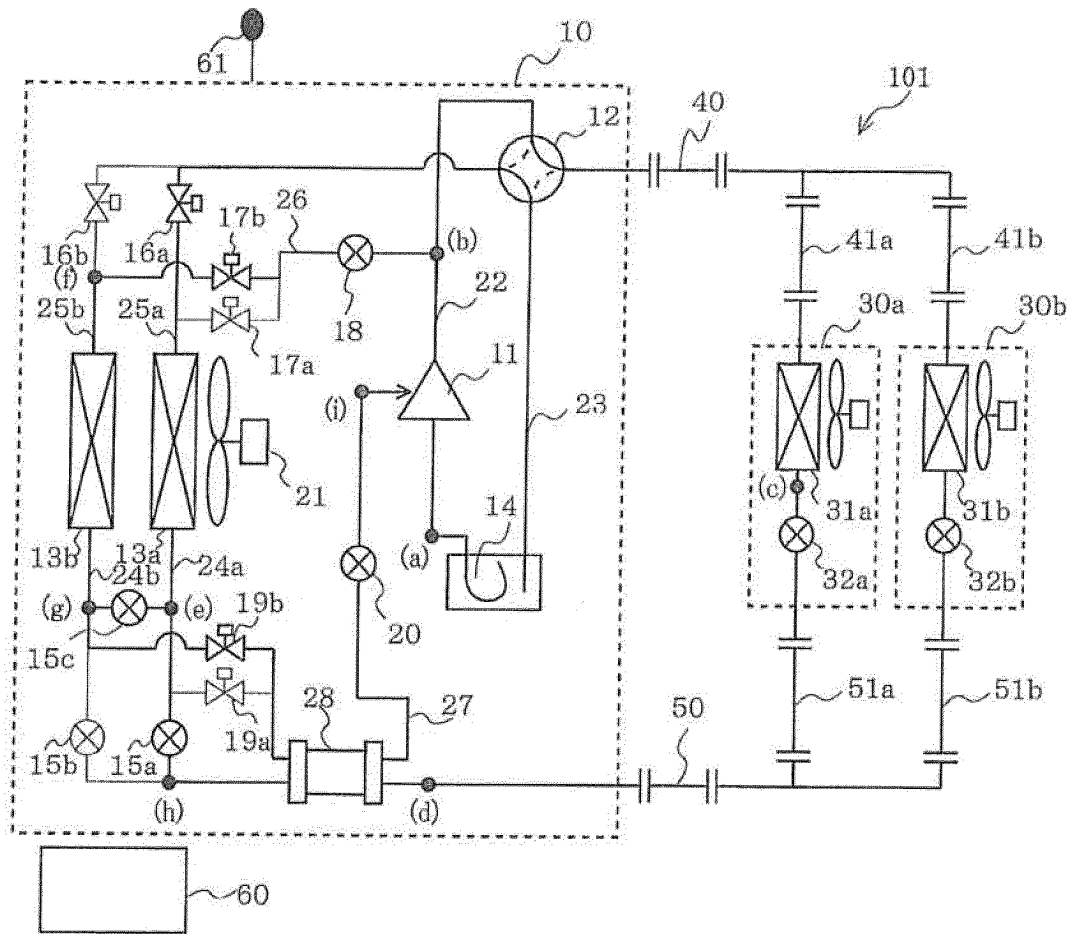


FIG. 19

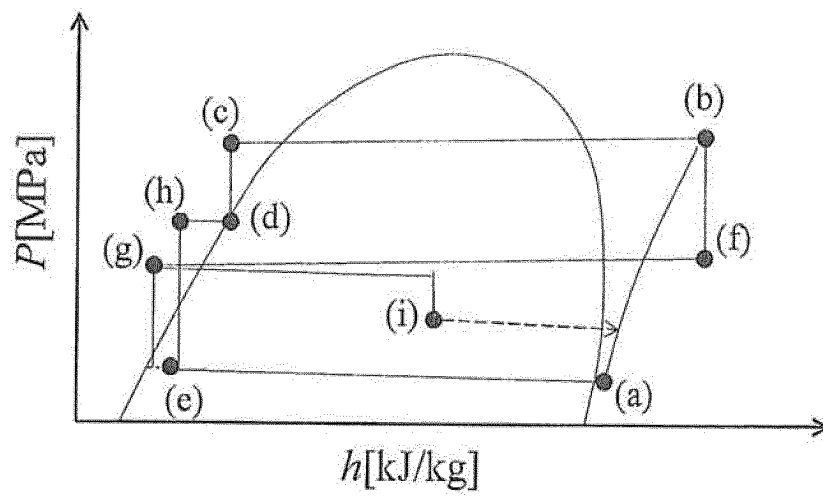


FIG. 20

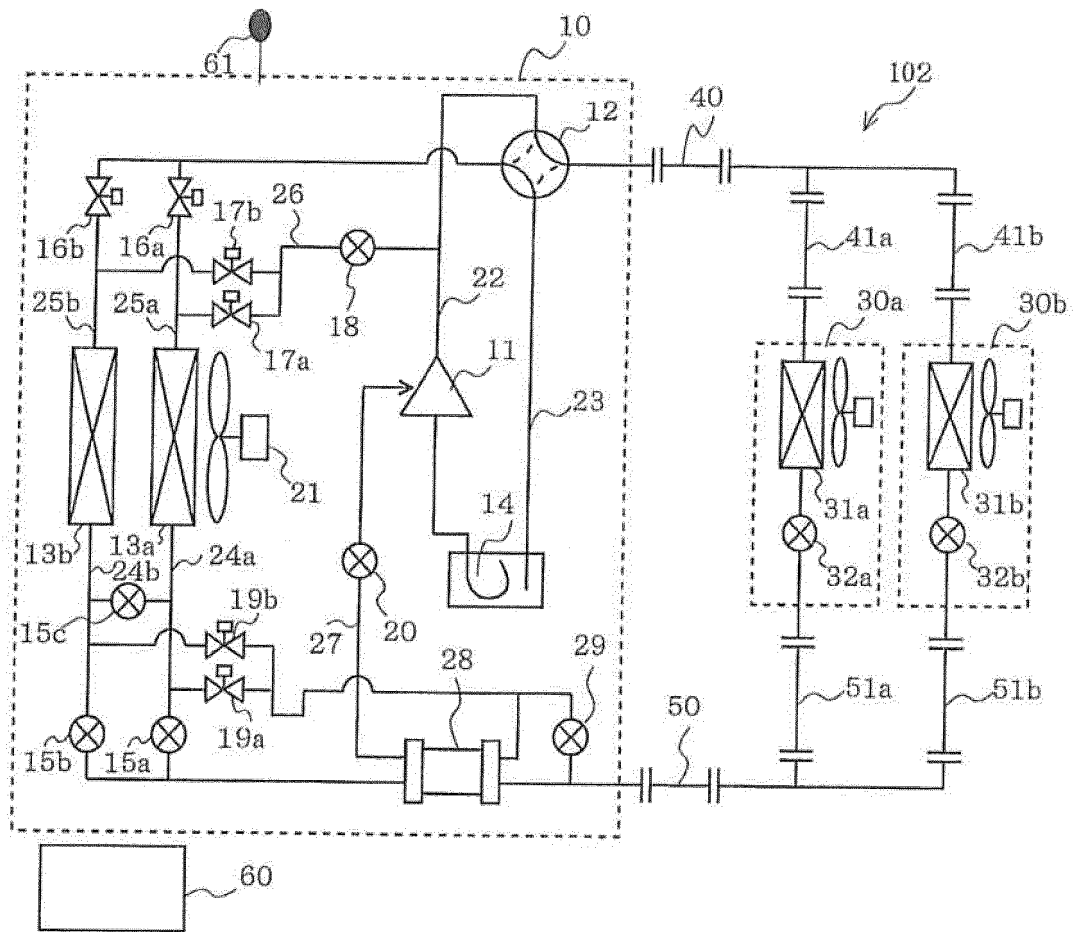


FIG. 21

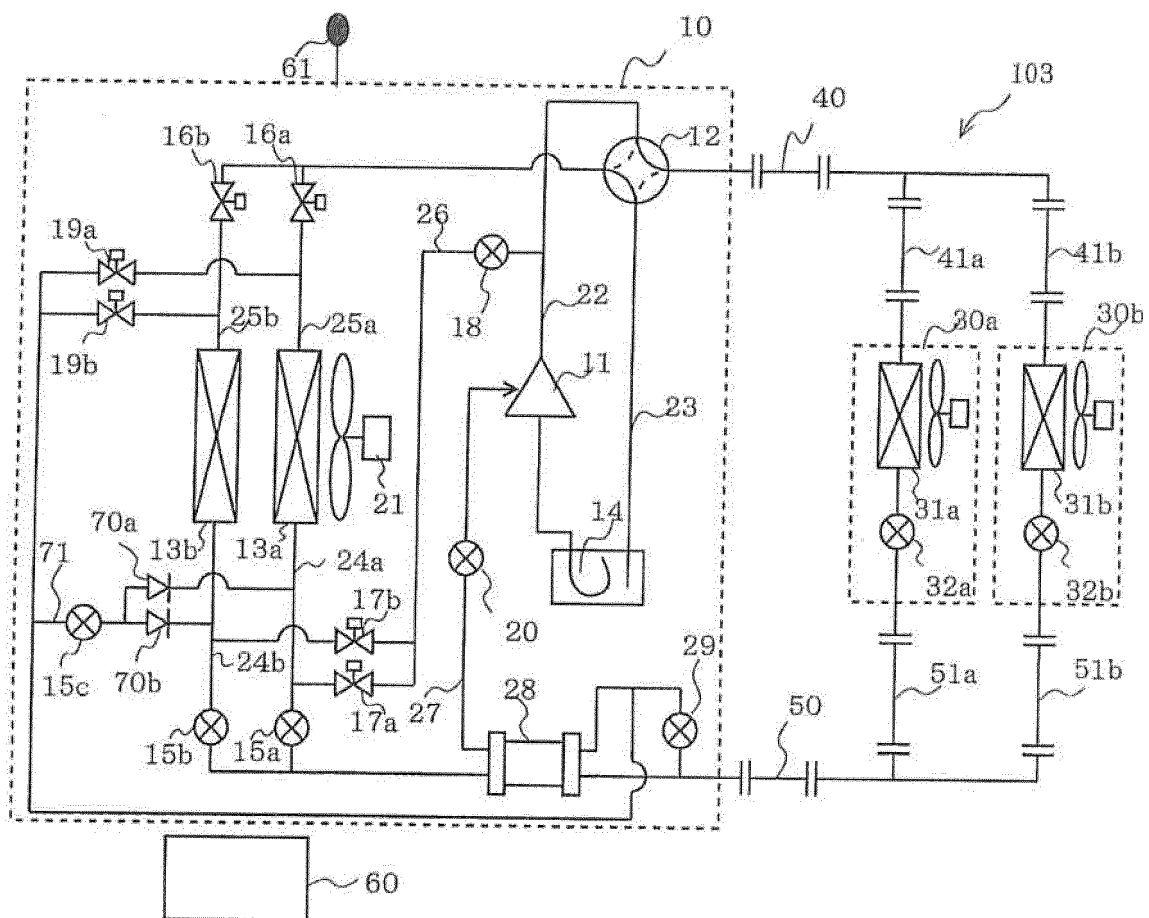
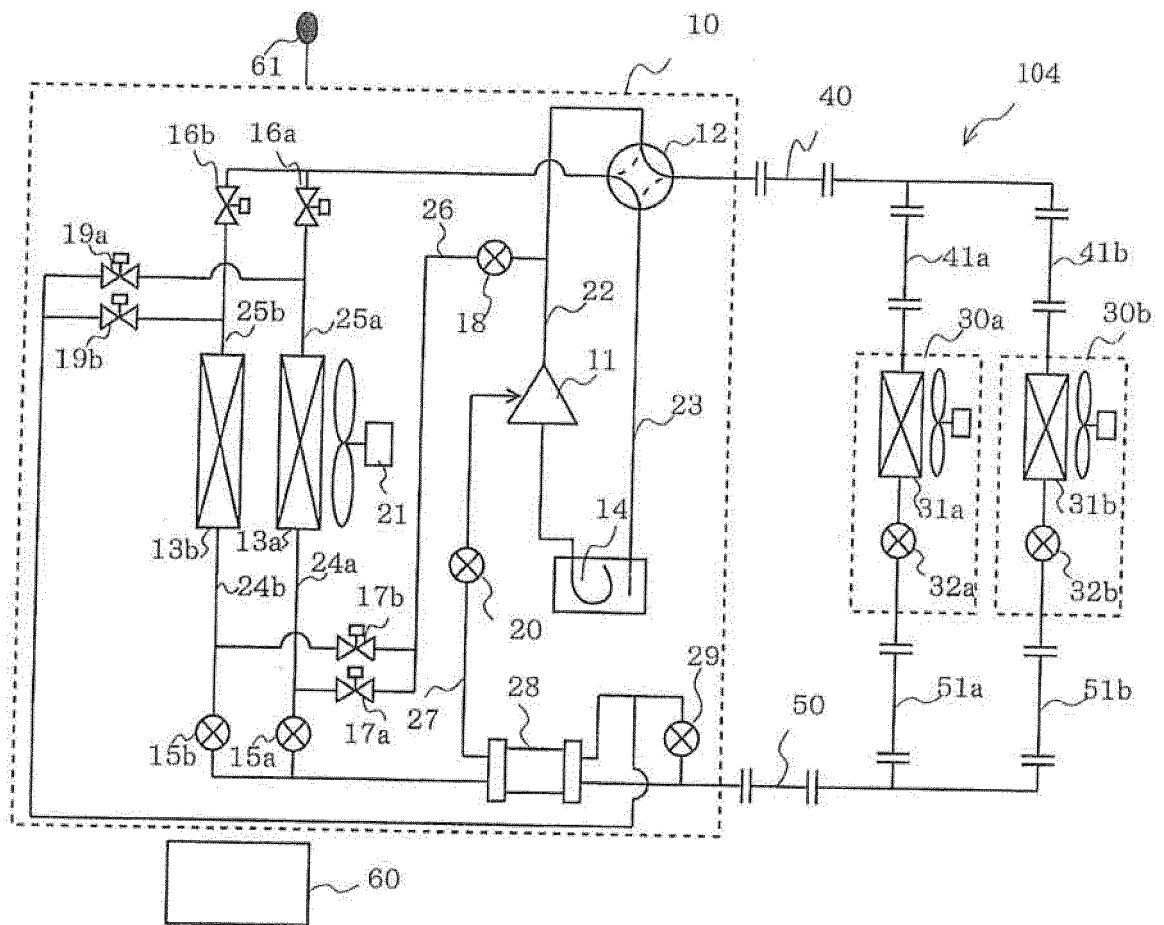


FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/065210

A. CLASSIFICATION OF SUBJECT MATTER

F25B47/02(2006.01) i, F25B1/00(2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B47/02, F25B1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013

Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/014345 A1 (Mitsubishi Electric Corp.), 02 February 2012 (02.02.2012), paragraphs [0016] to [0024], [0064] to [0075]; fig. 3, 4, 18, 19 & US 2013/0098092 A1	1-14
A	JP 2011-52883 A (Mitsubishi Electric Corp.), 17 March 2011 (17.03.2011), paragraphs [0102] to [0117]; fig. 13 (Family: none)	1-14
A	JP 2008-249236 A (Mitsubishi Electric Corp.), 16 October 2008 (16.10.2008), paragraphs [0042] to [0046]; fig. 1 (Family: none)	1-14

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
20 August, 2013 (20.08.13)Date of mailing of the international search report
27 August, 2013 (27.08.13)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/065210

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 57-108558 A (Ebara Corp.), 06 July 1982 (06.07.1982), page 3, upper left column, line 8 to upper right column, line 17; fig. 3 (Family: none)	1-14

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2009085484 A [0012]
- JP 2007271094 A [0012]
- WO 2012014345 A [0012]